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ROTARY GUN CARRIAGE AND TRANSIT PLATFORM APPLIED TO THE SPANISH WAR VESSEL CHICAMAUGA.

Designed by CAPTAIN ERICSSON.

From "Army and Navy Journal."

The accompanying illustration represents a new system of transferring the battery from side to side without resorting to the complicated method of pivoting, practised in our vessels of war. In addition to the advantage of rapidly transferring the guns from side to side, an all-round fire is also secured by this new system, as will be seen by the following description:

The readers of the "Journal" will remember that our account of the famous thirty Spanish gunboats (see Vol. VII., Nos. 14 and 36), contained detailed plans of a rotary gun carriage, designed by Captain Ericsson, turning on a circular ring applied near the bow, the guns, as in the present case, firing *en barbette*. This plan of rotating the slide round a central pivot having proved successful on board of the gunboats referred to, the Spanish Government has recently procured an additional number of similar slides and carriages; while the new system of fighting either side of the vessel with a single battery, has been adopted on board of the *Chicamauga*. This system we now proceed to describe:

The leading features of the device is that of placing the gun carriage and its rotary slide on a circular platform supported on four cylindrical rollers (partially shown at *f f*) provided with flanges like the wheels of railway carriages. These rollers, the axles of which turn in appropriate bearings under the platform, move on two flat parallel bronze rails *l* and *m*, secured to the deck at right angles to the line of keel. One of these rails, *m*, is provided with cogs on the outside, thus forming a toothed rack. A small horizontal cogwheel under the platform, is geared into the said rack and actuated by a set of cogwheels arranged as in ordinary lifting jacks. The gear is put in motion by a vertical spindle having a handwheel attached to its upper end, the lower end being made to fit a square socket *n*, formed in the axle of the actuating pinion of the gear. It is hardly necessary to observe that after having transferred the platform to the desired position, the vertical spindle should be lifted out of its socket and removed, in order not to interfere with the free rotation of the slide. It may be mentioned that in addition to the gear referred to, suitable eyebolts are applied to admit of employing ordinary tackle in transferring the platform from side to side. Having been rolled into position on the fighting side of the vessel, say starboard, the platform must of course be secured by *two* fighting bolts. On of these is seen at *k*, the second of the pair being concealed by the slide. On rolling the platform to port, after having removed the fighting bolts, the latter will be inserted through the bolt holes of the lugs *g*, on the opposite side of the platform. It should be observed that, in

housing the gun, the fighting bolts will occupy diagonal positions, plates, as shown at *k*, being inserted in the deck accordingly.

Artillerists are aware that if the force of the recoil were brought to bear on the central pivot round which the slide revolves, the latter would be lifted up violently or seriously jarred at the instant of discharging the gun, since the vertical line passing through the centre of the trunnion is far in advance of the central pivot, when the gun is rolled out. To prevent such lifting or jarring, a very efficient expedient has been resorted to by the constructor, viz., that of attaching a bracket, *d*, at the forward end of the slide, extending about 2 in. below its base and bearing firmly against the circumference, *p*, of the platform. It will be readily seen that if the bracket referred to, which acts as a hook, be placed at a proper distance while the pivot round which the slide turns fits loosely in its socket, the force of the recoil will be received wholly by the edge, *p*, of the platform against which the bracket, *d*, bears. The professional reader cannot fail to perceive the advantage of transferring the strain from the central pivot in rear of the trunnion, to a point in *advance* of the same. Obviously the practical results will be that of causing the carriage and slide to bear down against the platform, instead of being violently jarred or lifted up, as it would be if the force of the recoil were brought to bear on the central pivot. Regarding the proper position of the fighting bolts for securing the platform during firing, it will be evident that, if inserted at *k*, as shown (for the sake of ready explanation) in the engraving, the platform would be lifted or jarred at the moment of discharging the gun; while by inserting the fighting bolt at *g*, the tendency will be to depress the platform, thereby securing perfect repose throughout the entire structure.

The gun-carriage itself, represented in our illustration, having been minutely described on a former occasion, as before stated, it will only be necessary to observe that the friction bar *c*, which in the original carriage was made of *iron*, has been made of bronze in all the recent carriages constructed for the Spanish Government, at the Delamater Iron Works. It was found in practice that the application of oil or grease to this bar, indispensable to prevent its corrosion, considerably diminished the friction, a circumstance of no importance if the diminution had been constant in amount; but the lubricating medium varying in quantity obviously caused irregularity in the intensity of the required friction. Bronze being now substituted for iron, renders the application of grease unnecessary, hence the friction between the wooden lining of the clamp *b* and the bar *c*, becomes uniform. Accordingly, by pushing the hand lever *a* to a given notch of the circular-toothed rack *s*, it has been found that the length of the recoil may be regulated with desirable exactness.

ON RETAINING WALLS.*

INTRODUCTORY.

In designing masonry works there is hardly any subject that presents itself more frequently than the retaining or revetment wall; and in some form or other it is found to enter into almost every design. To the military engineer no less than to his civil brother is the subject one of importance and interest, forming as the revetment wall does, for the most part, a component element in works of defence. To military engineers in truth is due some of the most valuable information that civil engineers possess regarding the theory of earth pressure, and although further considerations are involved in designing revetments for military works than the mere support of earthwork, there is still to be derived from the experiments and researches of military men information of much value to civil engineers. The subject is one that has received the fullest and most able treatment at the hands of mathematicians, and solutions for every case that could possibly occur in practice are to be found in our text-books. But the mathematical investigations of this and many other questions of common occurrence in practice, unquestionably valuable as they are, in determining the principle involved, and establishing final rules applicable to

* Practical Designing of Retaining Walls, by Arthur Jacob, A. B.

The present article is simply a reprint, with a few emendations, of the original essay. The edition was exhausted, but the work was still widely demanded by working engineers.

practice, are, it is believed, but rarely resorted to by practical engineers. Even when such examples have to be dealt with by those sufficiently acquainted with the mathematical mode of proceeding, they are generally solved without hesitation by some empirical rule, derived from experience. Such a method may, and doubtless occasionally does, lead to accident from weakness, and not unfrequently to clumsy waste of material and consequent expense. But it is not clear that less of failure or clumsiness would result if every retaining wall were calculated with mathematical precision, for in truth the data involved are so variable and imperfect, and the disturbing causes are of such a character as to neutralize to a great extent the accuracy of the investigation. With certain specific data theoretical accuracy can always be attained; but the engineer as a rule knows nothing with absolute certainty either of the weight of the earth he has to sustain in position, or of the masonry that he intends to adopt in doing so. These and other data he must assume before he enters on his calculations; and though there is not in these, as in many other investigations, any necessity to attempt an extreme degree of refinement, which would be inapplicable for every-day practice, yet there can be no good excuse for dealing with the matter by hap-hazard and guess-work.

It is not proposed now to regard with more than a cursory glance the principles involved in determining the strength of walls to support earthwork. Such simple rules will be given, as it is hoped will serve—due regard being had to the peculiarities of each particular case—to guide the less experienced in designing works of this class. The empirical mode of dealing with the question is clumsy and unscientific, whilst the formulæ usually given are so complicated as to render their application to practice out of the question.

SPECIFIC CAUSES OF FAILURE.

It must not be presumed that the failure and destruction of a retaining wall is necessarily due to the wall being of itself insufficiently strong. It may be quite heavy enough to resist the pressure of a bank, if due regard be had to the mode of forming the earthwork, and to drainage; but if these points be not fairly considered and observed at first, a retaining wall of quite sufficient thickness will probably give way sooner or later. As much care should in fact be devoted to the method of backing up and draining a wall, as to the calculation of its section; for indeed if these matters be disregarded, no retaining wall, properly so called, can be implicitly relied upon to stand. With the exception of one particular case, which will be noticed hereafter, walls are designed on the assumption that they are to support a dry material—or one, at any rate, not permeated by water—and that the material is to be deposited in such a manner as to have no predisposition to slide against the wall. It is, of course, also presumed that the wall shall be of fair workmanship and materials, and where these points cannot be relied upon, as is sometimes the case, especially in foreign works, some allowance should be made in the dimensions of the wall. It has not unfrequently happened that a retaining wall will have stood for a considerable number of years without showing any appearance of yielding, and yet will give way suddenly and completely, without apparent cause. Such failures can generally be accounted for by the fact of the wall not being designed to resist a maximum pressure, and never having been tried fully till the time of its destruction. Much apparent anomaly is observed in the way that retaining walls are found to fulfil the purpose for which they are designed: for whilst some will yield, others of less dimensions will continue to stand; such apparent inconsistency giving occasion for ingenious theories, most of them entirely unsupported by fact or experience. The truth is, that imperfect drainage, defective foundations, or rotten work will account for almost every conceivable case of failure.

FIRST CASE—HYDROSTATIC PRESSURE.

The first and simplest case of a retaining wall to be considered is that in which the pressure of water has to be counteracted; not indeed that the question in such a form belongs strictly to the subject under notice; but it nevertheless becomes absolutely the method of determining the strength of walls for certain positions. It not unfrequently happens, as in some hydraulic works or with the wing-walls of aqueducts, that the infiltration from behind, which is not always avoidable, may produce such a pressure as no retaining wall properly so called could be expected to bear. With this view the engineer's limit of safety will be attain-

ed when the structure is designed to sustain the full hydrostatic pressure. The pressure of water upon any plane surface immersed is known to be *equal to the area of that surface, multiplied by the depth of its centre of gravity below the level of the water, and by the weight of a unit of water.* Generally speaking the unit adopted in calculation is a foot; and the unit of water being taken at a cubic foot, weighing 62.5 lbs., the resulting product, from the multiplication of the three quantities, will give the *pressure* in pounds on the surface immersed. Let it be supposed for simplicity that water to the depth of 10 ft. has to be sustained by a vertical rectangular wall. It is usual to take but 1 ft. length of the wall for the calculation, though it will not affect the result whether 1 ft. or 100 ft. be the length assumed. We then have the surface under pressure = 10 sq. ft., the depth of the centre of gravity = 5 ft., and the weight of a cubic foot of water = 62.5 lbs.; the product of which quantities give us 3,125 lbs., the *pressure* on 1 ft. length of the wall. But this pressure is not the whole of the force that the wall has to resist; the leverage that it exerts must also be taken into account. In the example under consideration—namely, that of a vertical plane, with one of its sides coinciding with the surface of the water, as in Fig. 1.—the whole of the pressure is so distributed as to be equal to a single force acting at a point one-third of the depth from the bottom. Thus the total force to be resisted by the wall is $3{,}125 \times 3.33 = 10{,}416$, which is the *moment* tending to overturn the wall.

MOMENT OF RESISTANCE TO OVERTURNING.

It is evident that a certain weight of wall must be opposed to this overturning force; and as the height of the wall and the length are determined quantities, the thickness alone remains for adjustment. But as a rectangular wall in upsetting is considered to turn upon a single point, F, Fig. 1.—namely, the outer line of the foot of the wall, there will be a certain amount of leverage to assist the wall in resisting the pressure of the water. This leverage is the horizontal distance of the centre of gravity of the wall from the turning point F, and when the structure is rectangular and vertical, it is equal to half the thickness. *The amount of the wall's resistance will then be equal to the number of cubic feet in one foot of its length, multiplied by the weight of a single cubic foot of masonry, and by half the thickness of the wall.* Taking w = the weight of a cubic foot of water = 62.5 lbs., w^1 = the weight of a cubic foot of masonry, say 112 lbs.; x = thickness of the wall, and h = the height; the condition of simple stability will be fulfilled when

$$w^1 \times h \times x \times \frac{x}{2} = w \times h \times \frac{h}{2} \times \frac{h}{3} \quad (1)$$

$$\frac{w^1\, h\, x^2}{2} = \frac{w\, h^3}{6}$$

and solving for x we get

$$x = \sqrt{\frac{w\, h^2}{3\, w^1}} \quad . \quad . \quad . \quad . \quad (2)$$

The thickness of the wall = 4 ft. 4 in.

EXAMPLE.

A simple example has been selected for illustration, but of course a rectangular section of wall would not be found generally applicable in practice, nor would it be expedient to limit the dimensions of a retaining wall of whatever kind to the minimum that would sustain the pressure; some margin of safety must therefore be allowed, to cover inferior work and materials. It is true that no account has been taken of cohesion, which, if the wall be founded on rock or concrete, may be assumed to add to its stability about 7,000 lbs. for every square foot of base. In addition to this, practice seems to indicate an increase on the calculated thickness, and in the example the mean width might be augmented to 5 ft., the stability being further increased by altering the section from a rectangle to a battering wall with offsets at the back.

A good general rule for the dimensions of a wall designed to support water or earth in a semi-fluid condition will be—

Top breadth	= 0.3
Middle do.	= 0.5
Bottom do.	= 0.7

The height being represented by unity.

Proceeding to the consideration of walls for the support of dry earth, it will be found that the question is one that will in general require the engineer to exercise his judgment, to determine what angle of repose he will base his calculation upon. The natural slopes assumed by earths of different tenacity are so various, that an average figure cannot be adopted with safety; the calculation of pressure from earth, in fact, depends

essentially on this point, and a disregard of it will lead to very doubtful results. The following are a few of the slopes assumed by different materials, but it is probable that the engineer's judgment will be of more service than any table in deciding the angle of repose. The examination of a district in which works are intended to be carried out will always suffice to satisfy the designer of the nature of the material that he is dealing with, and may enable him to proportion his works very nearly to the requirements of safety and economy:—

	Angle of repose.	Slope.
Dry sand, clay and mixed earth	From 37° .. to 21° ..	1.33 to 1* 2 62 to 1
Damp clay	45° ..	1 to 1
Wet clay	From 17° .. to 14° ..	3 23 to 1 4 to 1
Shingles and gravel	From 48° .. to 35° ..	0.9 to 1 1.43 to 1
Peat	From 45° .. to 14° ..	1 to 1 4 to 1

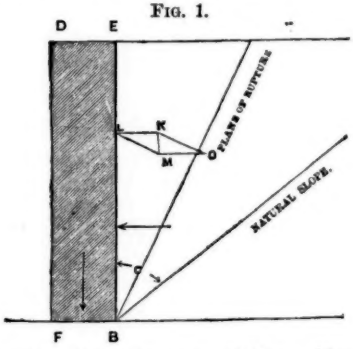
To which might be added as a special feature London clay; it appears under the influence of weather to be exceedingly unstable, slipping away to almost any angle of repose.

THEORY OF EARTH PRESSURE.

It has been ascertained by M. Prony that when a vertical wall sustains the pressure of a bank of earth the top of which is horizontal, the maximum horizontal pressure to which the wall can be subjected will be reached when the plane of fracture of the earth bisects the angle that would be formed were the earth to slope from the foot of the wall backwards at the natural inclination. This fact is somewhat striking, for it would appear at first sight, and was for long assumed, that the angle of fracture ought to coincide with the natural slope of the earth; such is, however, not really the case. If we suppose the angle made between the sloping plane and the vertical to be bisected, the prism of earth enclosed between the bisecting plane and the wall will represent the mass, the pressure of which has to be resisted; and this being the *maximum* pressure that a horizontal topped bank is capable of exerting, it is usually the point to be determined.

Referring to Fig. 1, the principle of earth pressure will readily be understood. Supposing the plane of rupture to bisect the angle c—which will be the case when the pressure is a maximum—the prism cut off will be the whole weight that the wall will have to sustain. Taking this prism for a single unit of length or thickness, the superficial area will represent the cubic

FIG. 1.



contents. But the area of the triangle, taking h as the height of the wall, will be

$$\frac{h^2 \tan. \frac{1}{2} c}{2}$$

c being the angle contained between the natural slope of the earth and the back of the wall. It is only necessary to multiply this value by w, the weight of a cubic foot of the bank, to get the total weight of the prism. This prism of earth is then like any other body resting upon an inclined plane; which in this case is the plane of rupture. It is sustained in position by the wall on one side and by the fixed portion of the bank on the other; and may be regarded as a solid mass of material without motion amongst its parts. The line K M represents the direction of the force of gravity, and the lines K L and K O the pressures exercised against the wall, and the force of the bank respectively. These pressures produce a certain amount of friction against the wall and the bank, but, as the friction against the wall does not materially affect the question, the friction of the bank alone is considered, and taken into account in arriving at the following formula which applies to the case of a vertical wall supporting a bank with a horizontal-topped bank:—

$$P = \frac{w h^2}{2} \tan.^2 \tfrac{1}{2} c \quad . \quad . \quad (3)$$

Having calculated the *pressure* of the earth, the next step will be to determine its *moment* to overturn the wall, and this can be ascertained, as in the case of water, by

* Rankine's "Manual of Civil Engineering."

multiplying the pressure by one-third of the wall's height. This having been determined the next consideration will be, what weight of wall will suffice to sustain it; and the method of arriving at this is similar for the most part to that adopted for water. Taking, as above, the moment of the wall to resist the pressure, the following equation will represent the conditions of stability:—

$$\frac{w' h x^2}{2} = \frac{w h^2}{2} \tan.^2 \tfrac{1}{2} c \frac{h}{3}$$

And solving for x, the thickness of the wall, we have—

$$x = \sqrt{\frac{w h^2 \tan.^2 \frac{1}{2} c}{3 w'}} \quad . \quad . \quad (4)$$

If the weight of a cubic foot of earth be taken equal to a cubic foot of the wall, the value will be—

$$x = \sqrt{\frac{h^2 \tan.^2 \frac{1}{2} c}{3}} \quad . \quad . \quad (5)$$

which would give a thickness of 2.69 ft. for a rectangular wall of 10 ft. high supporting a bank of earth, the angle of repose being taken at 40 deg. The average weight of brickwork and ordinary clay will generally be nearly the same; but if great accuracy be desired, and the respective weights of the materials be known, the general formula No. 4 must be used.

The following table gives the weight per cubic foot in pounds avoirdupois of such materials as come under our consideration in solving questions relative to retaining walls:

	Weight of a cubic foot in pounds.
Sand—damp	120
Do. dry	90
Marl	100
Clay	120
Gravel	125
Brick	130
Brickwork	112
Masonry	130
Mortar	110

PARTIAL RETAINING WALL.

Having so far considered the first two cases, namely, those of a wall supporting a horizontal-topped bank of earth in a semi-fluid condition, and also in a state of comparative dryness, the next example that suggests itself to our notice for examination is that of a partial retaining wall, or a wall from the top of which the bank slopes away for a certain height—called the surcharge—either at the natural slope of the earth or at a less inclination. Such mode of construction is of very common occurrence, dwarf walls being frequently adopted on railway works where the cuttings or embankments are of considerable height, and when carefully designed are found to effect a saving of expense, both in construction and in the item of land. In cuttings the walls are carried up to such a height as economy dictates, and the slope is then trimmed back at the proper angle. Similarly with embankments, the walls are so disposed as to cut off the foot of the slope. In either case a little consideration will suffice to show whether the saving of earth and land area will cover the cost of the retaining walls. In military works, as well as civil, the partial revetment is very commonly used, being, indeed, a component part of almost every system of fortification.

The first particular case belonging to this class, though not of the commonest occurrence in civil practice, is when a partial retaining wall supports a bank, the face of which slopes back at an angle less than the natural slope of the earth. As M. Prony's rule, that the plane of rupture bisects the angle between the natural slope of the earth and the back of the wall, only holds good when the surface of the bank is at right angles to the plane of the wall, another mode of determining the angle for the maximum pressure must be resorted to. The simple construction given in the note enables us to arrive at the maximum pressure for a wall at any given batter, with the surcharge above sloping at any inclination. The equation arrived at is the expression for the maximum horizontal pressure:

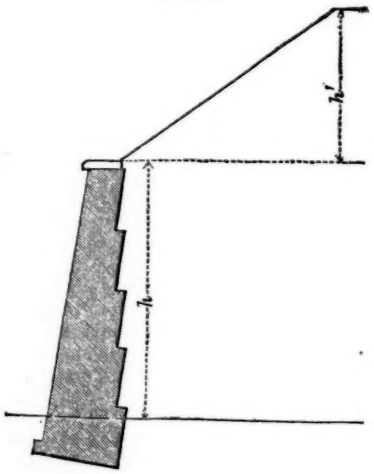
$$P = \frac{w h^2}{2} \times \frac{\tan. \theta \tan.^2 (c - \phi)}{\tan. \theta - \tan. c} \quad . \quad . \quad (6)$$

the angle c being that between the back of the wall and the natural slope; $\theta =$ the angle made by the face of the bank with the plane of the wall; and $\phi =$ the angle between the plane of rupture and the back of the wall. The value for $c - \phi$ will be found in the note. Taking, for example, a vertical wall of 10 ft. high, supporting a bank that slopes back at an inclination of 20 deg. with the horizon, the natural slope being 40 deg., the value of tan. $(c. - \phi)$ will be .4610; inserting this value and working out the equation, we arrive at a pressure of 2,100 lbs. against the back of the wall.

For the case of a revetment sustaining a surcharge the centre of pressure will be, as in the former case, at one-third of the height

of the wall, giving a leverage of 3.33 feet. This gives 2,100 lbs. $\times$ 3.33 = 6,993, the moment of the earth tending to overturn the revetment. Equating this value to the moment of the wall, taking the cube foot of brickwork at 112 lbs., the same weight as the earth, and solving for x the thickness, we find it to be 3.53 ft.

FIG. 2.



DEFINITE SURCHARGE.

The next case to be considered is one of much more frequent occurrence in practice than that just mentioned; it is a partial retaining wall supporting a surcharge of earth, sloping away at the *natural* inclination, and terminating in a horizontal plane above. Cuttings and embankments partly supported by masonry works furnish familiar examples of this, which is denominated the "definite surcharge." The most convenient method of determing the thickness of wall in this instance will be to consider, first, the conditions of stability for an infinitely long slope, which, however, can only have a theoretical existence; and having arrived at the thickness of wall necessary to support such a bank, a simple reduction will give the thickness required when the length of slope is limited.

It has been mentioned that when a vertical wall sustains a bank with a horizontal top, the plane of rupture for the maximum pressure is found to bisect the angle between the natural slope and the vertical. It is also an ascertained fact, that as the angle of the surcharge increases, the angle ϕ, or that between the plane of rupture and the back of the wall, also increases; until the face of the bank slopes at the natural inclination of the earth, and then the plane of rupture becomes parallel to it. From this it would appear that when the slope is infinitely long—a condition that could not exist in practice—the pressure will also be infinitely great; but such is not really the case. The ratio of the pressure of a bank, whatever its inclination, to the pressure exerted by an embankment level with the top of the wall can never exceed 4 : 1. The formula, then, for finding the maximum horizontal pressure exerted by an infinitely long slope against a vertical wall will be—

$$P = \frac{w h^2}{2} \sin.^2 c \quad . \quad . \quad (7)$$

the notation being exactly the same as in the other cases If we work this pressure out, using the same values for w, h, and c, as taken above, we shall find P=3,281 lbs.

Now for the leverage: we have, as in every other case, simply to divide the height of the wall by 3, which in our example gives 3.33 and the moment to overturn the wall = 3,281 $\times$ 3.33=10,925. Proceeding in the same manner as before, the width of a wall of brick to counterbalance an infinitely high bank sloping at the natural inclination, will be found to be 4.43 ft.

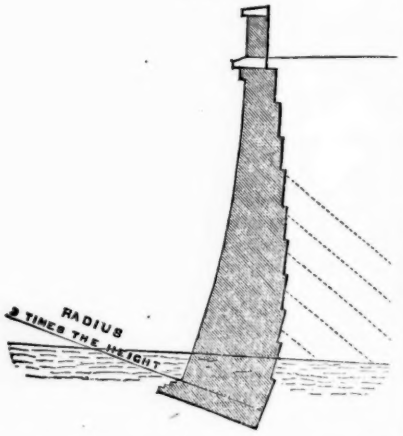
When the surcharge is very high as compared to the height of the wall, no reduction of the thickness will be necessary, for practically the slope may be considered infinite; but when the bank does not overtop the wall by a great height it will be well to apply the following formula to ascertain the corrected thickness. Let h= height of wall=10 ft., h'=height of surcharge above the wall, which we shall take at 20 ft., t=thickness of wall to support a horizontal bank, as found in the first case =2.69 ft., T=the thickness of a wall for a 20 ft. surcharge, t'=thickness for indefinite slope as found=4.43. Working this out the thickness is found to be 408 ft.

$$T = \frac{h t + 2 h' t'}{h + 2 h'} \quad . \quad . \quad . \quad (8)$$

So far we have considered the cases of more usual occurrence in practice, namely those in which the back of the wall is vertical or stepped, which is practically the same thing. For the calculation of leaning walls

the reader is referred to the general formulas (A) and (B) given in the note; from the latter formula the horizontal resistance of any bank, supported by a wall at any angle of inclination, can be ascertained, and the leverage being in every case taken at one-third of the height of the wall, there will be no difficulty in designing a wall of such a section as will resist the pressure of the bank effectually.

FIG. 3.



The point to be kept in view is the moment of the wall, and this must be made to *exceed* the maximum overturning force of the embankment. It will not suffice to *equalize* the moment of the earth's force to the resistance of the wall, as has been done in the examples above; a certain excess of resistance will be necessary, and this can easily be attained by giving the wall a batter, or else sloping it back so as to throw the centre of gravity of the mass as far back as possible, in a horizontal direction from the outer line of the foot of the wall. The line of the centre of gravity must not, however, be allowed to fall inside the base of the wall, otherwise the stability of the structure will become dependent on the support of the bank, and will have a tendency to slide away from its position.

It has been stated, and taken for granted, that banks of earth, when they destroy retaining walls, do so by turning them over; this is, however, not invariably the case. It has occasionally happened that walls have been moved bodily forward, sliding on their base. Such an occurrence is certainly accidental, and is probably the result of the wall having been founded on an unstable material, perhaps on an inclined bed of moist and uncertain soil. Walls have also given way in rare instances by the upper courses of the structure yielding to pressure, breaking off and falling over; a contingency that is probably due to the upper part of the bank becoming suddenly charged with water, and exercising an undue pressure on the wall before there is time for the water to drain away. These must be regarded as rare contingencies, arising out of some defect of the foundations, or backing; and cannot affect the consideration of the wall's stability generally. The theory of the wall being turned over on its base provides for the greatest trial to which the structure can be subjected, or, in other words, the wall would as a general rule give way under a much less pressure by falling over, than would be required to overcome friction, and move the wall forward in its entire state; if therefore the structure is considered as having to withstand the overturning force, it will always be strong enough to resist being pushed forward.

RETAINING WALL WITH CURVED BATTER.

A form of retaining wall commonly met with in practice, especially in brickwork structures, is that with a curved batter, stepped in offsets at the back. The curve usually adopted is the arc of a circle, the radius of which is from $2\frac{1}{2}$ to 3 times the wall's height; and the centre of the curve is as a rule in the same horizontal plane as the top of the wall. In such structures the courses are made to radiate from the centre, and the result is that the joints of the brickwork at the back are thicker than is either necessary or advisable. When the radius of curvature is large, the increase of thickness is inconsiderable, but it becomes decidedly an objection when the curve is a short one; for the thickness of the wall will not become reduced in the same proportion as the height or as the radius of curvature. The dimensions of a wall of this kind may be determined with sufficient accuracy, by first considering it as a leaning wall at a given slope, and using the general formula (6), and in this manner a very close approximation to the thickness may be arrived at. There are, it is true, specific formulæ given by some authors for determining the thickness of curved walls, but they are too complex for application in practice. The

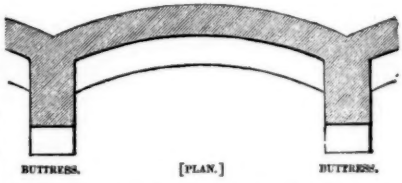
effect of the curvature will be to add to the wall's stability by bringing the centre of gravity farther in towards the bank, and this, indeed, is the only advantage that the curved form possesses; it is difficult to construct, and consequently expensive; for the saving of material, if any, is very trifling. In architectural effect it certainly has no advantage over the wall with a straight batter, for the simple reason that it does not convey the same idea of strength. If the curved wall is supposed to derive any additional stability from its curvature, on the principle of the arch, as some have fancied, it must be recollected that an arch with but one abutment is a very unstable kind of structure, and such kind is simply what the curved retaining wall is. Quays and river walls may, indeed, be designed of a curved form with advantage, for such will allow of ships coming closer to the brink, than they could were the wall a straight one. And sea walls, also, are not unfrequently built of a curved section on the face, this form being under certain circumstances better adapted than a straight wall to resist the force of waves.

In situations where a retaining wall has but one purpose to fulfil—that of supporting a bank of earth—it is usual to give the base of the wall a certain amount of inclination to the horizontal, the slope being perpendicular to the batter of the face; or if the wall have a curved batter, the plane of the base will simply radiate from the centre of curvature. Such mode of construction is calculated to increase the frictional stability, for it brings the thrust of the earth from behind more nearly perpendicular to the bearing surface.

COUNTERFORTS.

Counterforts are frequently constructed at the back of retaining walls, and, although generally approved of, appear to be a somewhat doubtful mode of distributing material. Mr. Hosking, in a paper read before the Institute of Civil Engineers, deprecates their use and, with some reason, advocates the use of ribs or arches from wall to wall. These ribs seem to have been suggested by the cast-iron beams used to support the falling walls on the London and North Western Railway between Euston Station and Primrose Hill. Mr. Hosking proposes that his arches of brick should pass completely over the road, and that they should consist on plan of a pair of flat arches placed back to back. Such an arrangement would doubtless prove effective, and the expediency of adopting it would evidently be determined by the cost of the work and the value of land adjoining—a mode of construction in common use in metropolitan works, and in other situations where land is very valuable, is that shown in Fig. 4. It consists of a series

FIG. 4.



of buttresses and inverts, the convexity of which latter is opposed to the thrust of the backing. Such a distribution of material is most suitable in situations where the projection of the buttresses is not found inconvenient. In quay and river walls it would not answer of course to have any such projection, as the near approach of ships and boats is an essential consideration.

The distribution of the material in the form of counterforts is attended with a slight saving, and where buttresses would be inadmissible on account of their encroaching on the roadway, counterforts may be adopted. They have at least one use, that they oppose more friction to the earth than a plain wall, and, being easy of construction, are productive of but little additional expense. In order to ascertain what additional mean thickness a wall derives from the counterforts, it is only necessary to *multiply the length of the counterfort by its mean width, and divide the product by the distance from centre to centre* of two counterforts. The form and dimensions of counterforts vary with circumstances, the narrow and deep disposition of the material being probably the best as a general rule. The late Lieutenant Hope, of the Royal Engineers, conducted some interesting experiments on the stability of retaining walls generally, and arrived at the conclusion that a thin wall, with frequent thin counterforts, was the best arrangement of the material.

Two points of importance relative to counterforts demand particular attention—the first, that they should be built simul-

taneously with the wall; and the second, that the wall should be well bonded into the counterforts, otherwise they detract from the wall's strength, instead of augmenting it. It is evident that without some special system of bond, counterforts reducing the thickness of the wall, as they are generally understood to do, must prove detrimental rather than advantageous; but if plenty of hoop iron be used, which is not usually the case, counterforts may be made to contribute in a very considerable degree to the stability of the wall. In fact, quite as much as buttresses.

MODE OF BACKING AND DRAINAGE.

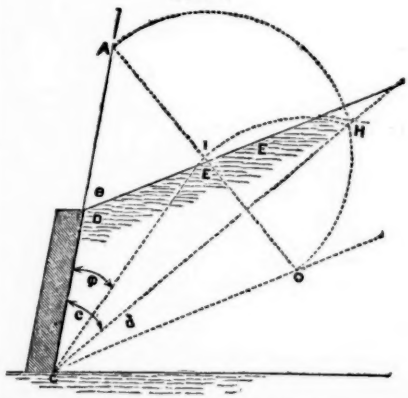
That accidents frequently occur from due care not being exercised in the mode of backing-up retaining walls is undoubted, and indeed to this cause alone the majority of failures is attributable; not, as is frequently supposed, to the insufficient section of the wall. The drainage of masses of earth sustained by walls, is a matter that can only be disregarded with risk of ill consequences. It is a difficult thing to prevent surface water from finding its way into earth-work, and therefore the simplest method of dealing with it will be to provide efficient means for its escape. To this end holes or *weepers* should be left in the wall at different levels, to relieve it from pressure from behind; and in order to admit the surface water to these points of escape, it will be advisable to back up the wall with dry stone, quarry shivers, or whatever else will admit the free passage of water. If a wall be backed up in this way by a rough angular material, it will be relieved of almost all pressure from the earth. Economy will, however, generally preclude such an expedient in works of considerable extent, and then it will be necessary to form the embankment with great care, adopting every precaution to prevent the tendency of the earth to slip in the direction of the wall. It will be evident from the calculation of the pressure exerted by earth, that the less the angle of repose is, the greater will be the pressure on the wall; and, as a matter of course, any means that will tend to increase the angle of repose, will relieve the wall of a certain amount of pressure. Effectual drainage will do much towards this end; but the mode of depositing the earth will also affect the angle of natural slope in a considerable degree. The same earth under different treatment will assume different slopes; if dry, it will fall when tipped—at a low angle, but if damped, and well rammed, will adapt itself to a much higher one. It has even been found that a bank when constructed in such a manner has stood for a considerable time perfectly vertical. The best mode of backing a wall up with earth will then be, to commence depositing at the foot of the wall, and to lay the earth in layers inclining *against* the wall, as shown by the dotted lines in Fig. 3, each layer being well rammed before another is commenced. This will not only consolidate the earth, and prevent any shock that might occur from sudden settlement, but will increase the angle of repose, and give the earth a tendency to slip away from the wall, rather than towards it.

THE LAND TIE.

An expedient for securing retaining walls that is simple and not expensive, is the land tie; it consists of an iron plate, with a rod passing through its centre, the plate being placed vertically in the bank behind the wall, and the end of the rod passed through the wall and secured. The holding power will depend on the area of the plate, and the depth at which it is sunk beneath the surface. But it is evident that, in order to act most effectually, land ties should be attached to the wall at the height of the centre of pressure.

NOTE.—The following construction, given by Mr. Neville in the "Transactions of the Institute of Civil Engineers, Ireland," vol. i., shows the method of determining the

FIG. 5.



pressure exerted by a bank, whatever may be its inclination:

Let C D represent the wall; D E the face of the bank sloping at any angle; and C H the line of natural slope. Draw any line perpendicular to the line C H, cutting the line of the wall produced at A, and also a line drawn parallel to the face slope at O. On A O describe a semicircle. From O, as a centre with the radius O H, describe an arc cutting A O in I: draw I C. The triangle C D F represents the maximum to be resisted. The angle $\delta = \theta - c$. The complement of the angle of repose $= \rho$; and the face C D $= h$

$$\tan.\ (c-\phi) = (\tan.^2 \delta + \tan.\ c \tan.\ \delta)\ \tfrac{1}{2} - \tan.\ \delta. \quad \text{(A)}$$

Putting R for the maximum *horizontal* resist-

TABLE A.

Table of coefficients of h for finding the Thickness of Standard Rectangular Walls, when the top of the bank is horizontal.

Ratios of W to W'.	1/1	1/1·1	1/1·2	1/1·3	1/1·4	1/1·5	1/1·6	1/1·7	1/1·8	1/1·9	1/2	1/2·1	1/2·2	1/2·3	1/2·4	1/2·5
Angle of Repose.							K	K	K							
0	.577	.550	.527	.506	.488	.472	.456	.443	.430	.419	.408	.399	.389	.381	.373	.365
30°	.334	.317	.304	.292	.282	.272	.263	.256	.248	.242	.235	.230	.224	.220	.215	.211
31°	.327	.311	.298	.286	.276	.267	.258	.251	.243	.237	.231	.225	.220	.216	.211	.207
32°	.320	.305	.292	.281	.270	.261	.253	.245	.238	.232	.226	.221	.216	.211	.206	.202
33°	.314	.299	.286	.275	.265	.256	.248	.240	.234	.228	.222	.217	.212	.207	.203	.198
34°	.307	.293	.280	.269	.260	.251	.243	.236	.229	.223	.217	.212	.207	.203	.198	.194
35°	.300	.286	.274	.263	.254	.245	.237	.230	.224	.218	.212	.207	.202	.198	.194	.190
36°	.295	.280	.268	.258	.248	.240	.232	.225	.219	.213	.208	.203	.198	.194	.190	.186
37°	.288	.274	.262	.252	.243	.235	.227	.221	.214	.209	.203	.199	.194	.190	.186	.182
38°	.282	.268	.257	.246	.238	.230	.222	.216	.209	.204	.199	.194	.189	.185	.182	.178
39°	.276	.262	.251	.241	.233	.225	.217	.211	.205	.199	.194	.190	.185	.180	.177	.174
40°	.269	.256	.245	.235	.227	.219	.212	.206	.200	.195	.190	.185	.180	.177	.173	.170
41°	.263	.250	.240	.230	.222	.215	.207	.202	.196	.192	.186	.181	.177	.173	.170	.166
42°	.257	.244	.234	.225	.216	.210	.202	.197	.191	.186	.181	.177	.173	.169	.165	.162
43°	.251	.239	.229	.220	.212	.205	.198	.192	.187	.182	.177	.173	.169	.164	.162	.158
44°	.245	.233	.223	.214	.206	.200	.193	.188	.184	.177	.172	.169	.164	.161	.158	.154
45°	.239	.227	.218	.209	.202	.295	.188	.183	.178	.173	.168	.165	.161	.157	.154	.151

TABLE B.

Table of coefficients of h for finding the Thickness of Standard Rectangular Walls, when the top of the bank slopes away at the Angle of Repose.

Ratios of W to W'.	1/1	1/1·1	1/1·2	1/1·3	1/1·4	1/1·5	1/1·6	1/1·7	1/1·8	1/1·9	1/2	1/2·1	1/2·2	1/2·3	1/2·4	1/2·5
Angle of Repose.							K	K	K							
30°	.500	.476	.456	.438	.423	.409	.395	.384	.372	.363	.353	.345	.337	.330	.323	.316
31°	.494	.471	.452	.434	.418	.404	.391	.380	.368	.359	.350	.342	.333	.326	.320	.313
32°	.489	.466	.447	.429	.414	400	.387	.376	.365	.355	.346	.338	330	.323	.316	.309
33°	.483	.461	.442	.424	.409	.395	.382	.371	.360	.351	.342	.334	326	.319	.312	306
34°	.478	.456	.437	.419	.404	.391	.378	.367	.356	.347	.338	.331	.322	316	.309	.303
35°	.472	.450	.431	.414	.399	.386	.373	.362	.352	.343	.334	.327	318	.312	.305	.299
36°	.467	.445	.426	.409	395	.382	.369	358	.348	.339	.330	.323	315	.308	302	.295
37°	.461	.439	.421	.404	.389	.377	.364	.345	.343	.334	.326	.319	.311	.304	.298	.291
38°	.455	433	.415	.399	.384	.372	.359	.349	.339	.330	.321	.314	.306	.300	294	.288
39°	.448	.427	.409	.393	.379	.367	.354	.344	.334	.325	.317	.310	.302	296	.290	.284
40°	.442	.421	.404	.388	.374	.361	.349	.339	.329	.321	.312	.306	.298	.292	286	279
41°	.435	.415	.397	.382	.368	.356	.344	.334	.324	.316	.307	.301	293	.287	.281	.275
42°	.429	.409	.391	.376	.363	.351	.339	.329	.319	.311	303	.296	.289	283	.277	.271
43°	.422	.402	.385	.370	357	.345	.333	.324	.314	.306	.298	.292	284	.278	.273	.267
44°	.415	395	.379	.364	351	.339	.32-	.318	.309	.301	.293	.287	.280	274	.268	.262
45°	.408	.389	.373	.358	.345	.334	.322	.313	.304	.296	.288	.282	.275	.269	.264	.258

ance, and w for the weight of a cubic unit of the bank, the resistance of pressure will be

$$R = \frac{w h^2}{2} \frac{\text{tan. } \theta \text{ tan. }^2 (c - \phi)}{\text{tan. } \theta - \text{tan. } c.} \quad . \quad . \quad (B)$$

in which the value $(c - \phi)$ found above must be substituted. When C D E is a right angle we shall have

$$R = \frac{w h^2}{2} \text{ tan. }^2 \tfrac{1}{2} c \quad . \quad . \quad . \quad (C)$$

the equation given in the first part of this article; and that which holds good when the slope of the bank is at right angles to the face of the wall.

The foregoing tables calculated by Mr. J. H. E. Hart, Executive Engineer of the Bombay Department of Public Works, are, by his kind permission, appended to this pamphlet, and will be found very convenient for the calculation of Retaining Walls.

Knowing the angle of repose of the earth to be supported, and the relative weights of the masonry of the wall and of the earth per cubic unit, a simple reference to the table will give a coefficient, which multiplied by the height will give the requisite thickness. For example, supposing a *horizontal* topped bank has to be supported by a masonry wall of 10 ft. high, and of twice the specific gravity of the earth, the angle of repose of the latter being 35 deg. Under the fraction $\frac{1}{2}$, and opposite to 35 deg., will be found in Table A the fraction .212, which multiplied by 10, the height of the wall, gives 2.12 ft., the required mean thickness.

RULES OF THUMB FOR STEAMSHIP SPEED, POWER, AND COAL, IN THE MERCHANT SERVICE.

From "The Nautical Magazine."

All readers of the "Nautical" are interested in the above items of steamship performance. It is proposed to give in the following paper a number of simple rules for the use of those who have not the time, or perhaps the training, for going deeper into the subject; and also to state some of the useful arithmetical contractions that reduce formidable calculations to a simple sum in mental arithmetic. These purely arithmetical rules are not new.

The speed of a steamer is the speed of the propeller, whether that be screw or paddle, less the slip. For the speed of the propeller we have the following rules:—

I. $\dfrac{\text{Revolutions per minute} \times \text{pitch in ft.}}{100} =$

knots per hour by screw.

II. $\dfrac{\text{Revolutions per minute} \times \text{pitch in ft.}}{88} =$

miles per hour by screw.

III. $\dfrac{\text{Revolutions per minute} \times \text{diam. in ft.}}{32} =$

knots per hour by paddles.

IV. $\dfrac{\text{Revolutions per minute} \times \text{diam. in ft.}}{28} =$

miles per hour by paddles.

In the first of these the knot is taken as 6,000 ft.—that is, it is reduced by about 80 ft.; the rule is only an approximation, but it is what is generally used by practical men. The second rule is quite correct; the third supposes about 50 ft. taken off the knot; and the fourth supposes about 14 in. cut off the statute mile. We give examples of these rules:—

1. A screw propeller makes 74 revolutions per minute, its pitch is 18 ft., what is the speed of the screw in knots and in miles per hour?

74	74
18	18
592	592
74	74
1332	8)1332
	11)1665
13 32 knots.	15.14 miles.

2. A screw propeller is 22 ft. pitch; how many revolutions per minute must it make for a speed of screw per hour of 14 knots, and for 14 miles?

22)1400(63 6	14
132	88
80	112
66	112
140	22)1232(56
	110
	132
	132

Answer. 63.6 revolutions for 14 knots, or 56 revolutions for 14 miles.

3. A paddle wheel is 28 ft. in diameter, from centre of float to centre of float; it makes 26 revolutions per minute; what is the speed of the floats in knots and in miles per hour?

28	28
26	26
168	168
56	56
4)728	4)728
8)182	7)182
22¾ knots.	26 miles.

4. A paddle wheel is meant to make 36 revolutions per minute, what diameter must it be if the speed of the floats is to be 18 knots, and what if 18 miles per hour?

18	18
32	28
36	144
54	36
36)576(16	36)504(14
36	36
216	144
216	144

Answer. 16 ft. diameter for 18 knots per hour, and 14 ft. diameter for 18 miles per hour.

In the calculation for screw speed in knots, we had 100 as a divisor, but to multiply or to divide by 100, is only to add or cut off two decimal places. In some of the following rules we have similar divisors, but they may be practically neglected, and the decimal place always fixed by inspection. In the first example there could be no hesitation as to whether it was 1.33 or 13.3, or 133 knots that was meant; and so, in other cases, it is often convenient not to burden the mind with the exact number of ciphers there is in the divisor; and, although we have in every case given them, they need not be committed to memory.

The marine engines in general use may be divided into three classes: common engines, with jet condensation, working with steam at 25 lbs. pressure, when new; common engines, with surface condensation and separate expansion valves, working with steam about 40 lbs. pressure, when new; and compound engines, working with steam abont 60 lbs. pressure, when new. We will call these three classes—common engines, surface condensing engines, and compound engines in the following rules:—

Rule V. The square of the diameter, in inches, of one of a pair of surface condensing engines, divided by 100, is the average consumption in this class of engine in tons of coal per day. The consumption for compound engines is one-fifth less, and for common engines one-fifth more than the above; that is, multiply by .8, or by 1.2, as the case may be.

For compound engines in this and all the following rules, reckon only the low pressure cylinders.

These are only "Rules of Thumb," and to introduce any factor for speed of pistor, or other refinements, would alter their character, and defeat the object we have in view in publishing them. For very fast running pistons the consumption will, of course, be greater, and for very slow moving pistons the consumption will be less.

Rule VI. The total width, in feet, of all the furnaces will be about the same as the consumption in tons of coal per day.

5. A pair of engines, cylinders 30 in. in diameter, what is the consumption of coal per day?

$30 \times 30 = 900$, say 9 tons, if surface condensing.

Say $9 \times 1.2 = 10.8$ tons, if common engines.

Say $9 \times .8 = 7.2$ tons, if compound engines.

6. A pair of common engines, 56 in. cylinders, how many furnaces, each about 3 ft. wide, will there be in the boilers, and what will be about the consumption of coals per day?

$56 \times 56 = 3.136 \div 100 = 31.36$.

$31.36 \times 12 = 37.6$, say $37\frac{1}{2}$ tons per day.

And say 12 furnaces each, 3 ft. $1\frac{1}{2}$ in. wide.

In marine high-pressure boilers the consumption is generally less than that given in Rule VI., and is even sometimes as little as 14 cwt. per foot of width for Welsh steam coal.

7. A compound engine, one high-pressure cylinder, 33 in. diameter, and one low-pressure cylinder, 62 in. diameter, what will be about the consumption of coal per day, and what number of furnaces, each about 3 ft. wide, will be suitable for the boiler?

Here we have only one engine, and as the rules are for a pair, we have to divide

by 2, and we do not reckon the high pressure cylinder.

62 × 62 = 124, 372, 2)3844, 1922

19.22 × 8 = 5)15.376 tons. 3.07

Say 15½ tons per day and 5 furnaces, each 3 ft. 1 in. wide.

Rule VII. For a maximum speed of 10 knots per hour, the diameter in inches of one of the cylinders of a pair of engines is about 1.4 times the beam of the vessel in feet. If there is only one engine, the diameter of its cylinder, in inches, is 2 times the beam of the vessel in feet.

Rule VIII. For any other maximum speed multiply the above results by that other speed, and divide by 10.

This rule is not correct in principle, but as the speed is, generally, not far from 10 knots, and as for greater speeds the engines generally give proportionately greater power, this approximation is frequently not far from the truth. The above applies to either of the three classes of engines described above.

8. The beam of a steamer is 38 ft., the vessel steams 12 knots; about what diameter are the cylinders, a pair of engines?

38 × 1 4 = 152, 38, 53.2

53.2 × 12 = 10)63.84, 63.84

Say 64 in. diameter.

9. A steamer, 36 ft. beam, steams, at her maximum speed, 11 knots per hour; about what diameter are the cylinders, a set of compounds?

36 × 2 = 72

72 × 11 = 72, 72, 10)792, 79.2 inches.

The low pressure cylinder will be about 79 in. in diameter.

Rule IX. The square of the beam of a vessel in feet gives the tons of coal for a speed of 10 knots per hour for 40 days, 50 days, or 60 days, according as the engines are common, surface condensing, or compound. Welsh steam coal is meant.

Rule X. For other speeds multiply the square of the beam, in feet, by the cube of the speed in knots, and divide by 1,000 before dividing by 40, 50, or 60 for the consumption per day.

10. A steamer is 36 ft. beam, the engines are compound, what is her consumption for a speed of 10 knots per hour?

36 × 36 = 216, 108, 60)1296, 21.6 tons.

11. A steamer has common engines, she steams 11 knots per hour, about what is her consumption per day—the beam is 40 ft.?

11 × 11 = 121, 11, 1331

40 × 40 = 1600, 1.331, 1600, 4800, 4800, 1600, 4(0)212(9 600, 53 24 tons per day.

If with compound engines, this would have been—

6(0)212(9, 35.5 tons per day.

Rule XI. The length of a steamer multiplied by the square of the beam, both in feet, divided by from 100 to 120, gives about the displacement of the steamer when at her deep load line—say average 110.

The displacement, and indeed all the other results we have given, vary very much, even in vessels agreeing in the dimensions referred to by us. Our rule supposes that all we know of the vessel is her length and her beam, and although the result cannot be taken as accurate, the approximation is often useful.

12. A steamer is 41 ft. beam, 433 ft. long, about what displacement will she have?

41 × 41 = 41, 164, 1681

1681 × 433 = 5043, 5043, 6724, 11(0)72787(3, 6617 tons.

Rule XII. The displacement by the cube of the speed in knots, divided by 12 times the length, is equal to the indicated horse-power.

The divisor 12 is about the average for a fair result, but it varies from 10, or even less, up to 14, and, according to some returns, even to 16. We doubt whether this high result has ever actually been obtained.

13. A steamer displaces 3,900 tons, she is 335 ft. long, her speed is 9.75 knots. About what horse-power will she indicate?

$$3{,}900 \times 9.75 \times 9.75 \times 9.75 = 3{,}614{,}500$$
$$335 \times 12 = \ldots\ldots\ldots\ldots\ldots \quad \frac{3{,}614{,}500}{4020} = 899.$$

Answer. 899 horse-power.

In concluding for the present our notice of these rules, we have to explain that our object is not so much to give rules that will give results in strict agreement with every example of steamship performance, as to give a shape to rules that can be modified by the reader, by altering the multiplier or divisor to be in accordance with his experience, and to give them in a form so simple that their application may be more an amusement than a tedious calculation.

We shall be glad to receive from any of our readers better values for any of the numbers we have given. The following is a list of worked out results, the data were sent in by a few friends, and indicate a great disparity between the performances of the different vessels. There is, no doubt, a difference in the manner of fixing the data; the steaming speed of a vessel is very different as given by different observers. Some will give the average speed upon the voyage involving the variable element of the effect of the wind; while some will give the speed from a trial trip, as running between the Lights on the Clyde. The length by some will be given the registered length, by others the length at load water line. The consumption is always only roughly measured; some include the coal used for cooking and for steam winches in the propelling consumption, while others deduct that, and, if disposed to make a very economical performance, they will even knock off a percentage for defective weight in coals supplied abroad. But, however these facts may cast doubt upon returns whose details cannot be verified, they may be all eliminated from any set of examples under one's own observations, which should all be taken in the same manner.

In the following heading B is the beam, to the speed in knots per hour, C is tons of coal per day, L is length of vessel as reported, some of them are the registered length, others the length on water line; H is the indicated horse-power. The displacement is given as reported to us, so that our friends may recognize their own vessels and explain any discrepancies they may see in this comparison. The higher the numbers the better are the results.

ALL WITH COMPOUND ENGINES.

Displacement.	$\frac{B^2 . K^3}{1{,}000 . C} =$	$\frac{D . K^3}{L . C.} =$	$\frac{D . K^3}{L . H.} =$
1,500	42.7	380	10 4
1,730	77 4	632	15.1
1,810	77.0	675	10.8
1,973	61.5	500	12 7
1,980	33 4	335	8.6
2,010	71 9	691	14.3
2,197	66 6	677	14 1
2,175	56.1	541	13 7
2,450	31.1	298	7.1
2,720	61 9	576	15.7
3.425	59.4	528	11.8
3,890	82 9	837	14 2
3,900	35 7	371	12.0
4,200	83 0	610	15 1
4,870	53 9	552	16.0
5,240	55.4	397	11 2
6,480	61 5	570	13.7
6,750	64.5	598	14.4
Instead of as by the Rules..	60·	546	12.

Looking over this table we observe that the first example has the first two co-efficients of performance very low. This points to the coals as likely to be the faulty item, for that affects these two co-efficients; probably the coals are inferior or the return is too high, or possibly the boilers are too small and the coals waste by forcing the fires, or the engines may be bad. The third co-efficient 10.4 is not so exceptionally low as the other two. All the co-efficients compare proportionately, 5 per cent. on one has the same value as 5 per cent. upon either one of the other two.

When the number in the second column is equal to ten times the number in the first the displacement is then just equal to $\frac{L.\ B^2.}{100}$. A comparison of the two columns will show how this varies, in four examples this displacement is exceeded.

In the example 4,870, the displacement seems to us to be overstated, and hence the high value obtained for the third co-efficient, 16. The same remark seems to apply to displacement 2,720.

We recommend our readers not to be disappointed should these rules not apply closely to the examples they may try, and we hope they will modify the multipliers to make them suit, and let us know the result.

NOTES ON THE RESISTANCE OF BRICKS TO A CRUSHING FORCE.

By GEORGE S. GREENE, Jr., C. E.

From "Transactions of Am. Society of Civil Engineers"

The bricks were of the kind used in the construction of the South Gate-House of the New Reservoir in the city of New York, by Fairchild, Walker & Co., contractors.

The experiments were made by Gen. George S. Greene, at Cornell & Co.'s, Centre street, September 20th, 1860, in Hatfield's hydraulic press for testing building materials, built by R. Hoe & Co.

The bricks were what are known as hard brick, and manufactured at the yard of Wm. Call, Haverstraw, on the Hudson river; they are regarded as average samples of the mass of brick used in the construction of the gate-house. The experiments were not made in the interest of any person, but solely to determine the actual strength of the brick. In order to bring them within the power of the machine, but little more than half a brick was used. The pieces of brick were first dressed by a stonecutter, and then ground down on a grindstone. The faces exposed to pressure were not perfect planes, and therefore a layer of wood and sand was interposed between the faces of the machine and those of the bricks.

Dimensions of the Brick used in experiments, in inches and decimals.

	Thick.	Wide.	Broad.	sq. in.		
No. 1.—	2.30	× 3.52	× 4.40	15.488	exposed	to pressure.
No. 2.—	2.24	× 3.50	× 4.46	15.610	"	"
No. 3.—	2.34	× 3.50	× 4.52	15.820	"	"
No. 4.—	2.34	× 3.46	× 4.46	15.4316	"	"
No. 5.—	2.30	× 3.46	× 4.50	15.570	"	"
No. 6.—	2.28	× 3.46	× 4.66	15.916	"	"

No. 1.—At 30,000 lbs. (= 1937 lbs. per sq. in.) cracked in centre; kept at 50,000 (= 3,228.3 lbs. per sq. in.) without crushing. Brick between two pieces of board, half an inch thick.

No. 2.—Had a layer of sand. Sign of a crack at 50,000 lbs. (= 3,203 lbs. per sq. in.); kept at 52,500 (= 3,362 per sq. in.) for three minutes, but did not crush. Crack did not extend through brick, nor was it broken into two parts.

No. 3.—Crushed to pieces at 43,500 lbs. (= 2,748.7 lbs. per sq. in.); packed with sand.

No. 4.—Packed with two pieces of cigar-box wood; edges crushed off at 30,000 lbs. (= 1,994.1 lbs. per sq. in.).

No. 5.—Packed with sand; cracked at 27,000 lbs. (= 1,734.1 lbs. per sq. in.); crushed at 32,000 lbs. (= 2,055.3 lbs. per. sq. in.). Brick crushed and cracked in all directions; did not fall to pieces as did No. 3.

No. 6.—Packed in sand; commenced to crack at 30,000 lbs. (= 1,884.9 lbs. per sq. in.); crushed to pieces at 46,500 lbs. (= 2,921.6 lbs. per sq. in.).

The State Mineralogist of Wisconsin announces that there is enough iron ore in the neighborhood of the Black River Falls to supply the whole demand of the United States for the next ten centuries.

BOILER EXPLOSIONS.*

By ZERAH COLBURN.

A well-made steam boiler cannot be burst or torn open except by a great force. The internal pressure required to rend open a cylindrical boiler may be approximately calculated for any size of boiler and thickness of plates. With a boiler 3 ft. in diameter, and 10 ft. long, the plates, if $\frac{3}{8}$ in. thick and riveted in the ordinary manner, oppose at least $65\frac{1}{2}$ sq. in. of resisting section to any pressure tending to burst the boiler longitudinally open, or in the direction of its least resistance. A section of $65\frac{1}{2}$ sq. in. of iron, of average quality, would not yield under a tensile strain of much less than 1,462 tons (the resistance of the iron being taken as 50,000 lbs. per sq. in.), and this amount of strain could not be exerted by the steam within a boiler of the assumed dimensions, except at a pressure of at least 758 lbs. per sq. in. Such a boiler, therefore, if worked at a pressure of less than 125 lbs. per sq. in., would appear to be beyond all danger of explosion.

This very large apparent margin of strength has been taken by many as sufficient to justify the hypothesis of some violent internal action, at the instant preceding the actual rupture of a steam boiler; the rupture being regarded as the consequence of such action, and not of a mere pressure, which, until the ruptured parts are in motion, can only act statically. In hypotheses of this kind electrical action, the detonation of explosive gases assumed to be collected within the boiler, and the sudden production of steam from water thrown on hot plates, have been variously assigned as the causes of internal concussion. Such hypotheses have derived a certain amount of probability from the fact that there are perhaps as frequent instances of the quiet rupture of steam boilers as there are of their violent explosion. A simple rupture, attended only by the loss of the steam and water in the boiler, can of course occur only (under the ordinary working pressure) in consequence of the failure of a particular plate or seam of rivets; either from original defects in the material, imperfect construction, or from some injury which the boiler has sustained either at or before the moment of rupture. Such ruptures, being but rarely attended by any serious consequences, are seldom publicly reported. Their frequent occurrence, however, might appear to exhaust the explanation by overpressure, so perseveringly urged by Mr. Fairbairn and others in all instances of the violent explosion of steam boilers.

Without, however, at present considering ourselves bound either to accept or to reject the explanation of steam boiler explosions by steadily accumulated pressure, we may consider the probability or otherwise of the various explanations which assume the sudden production of great quantities of steam from water thrown upon red-hot plates; electrical action; the decomposition of steam and detonation of hydrogen in contact with air, etc., etc.

OVERHEATING.

Although it is possible that boilers may be exploded, in consequence of the formation of a great quantity of steam from water thrown upon red-hot plates, overheating cannot be assumed as being the general cause of explosions, which very frequently occur where there is abundant evidence, both before and after the disaster, that no overheating has taken place. Explosions have happened in many cases when, but a moment before, the water-gauges indicated an ample supply of water; and, in such cases, as well as in others, where there was positive evidence as to the amount of water in the boiler, the furnace-plates have been found in a perfectly sound state, or at least without any appearance of having been burnt. Burnt iron can be recognized without difficulty, and the fact that the plates of an exploded boiler show no signs of having been burnt may be taken generally as proof that they have never been overheated after having been made up in the boiler of which they formed a part.

Supposing, however, extensive and severe overheating to have taken place, and water to be suddenly thrown upon the heated plates, it is doubtful if the quantity of steam disengaged would be sufficient to

* This essay, by the late Mr. Colburn, was written something more than ten years ago, but the knowledge afforded by our later experiences would enable us to add but little, if anything. That the essay is still widely demanded, and that it has long been out of print, are the excuses for affording it a place in our pages at the present time.

increase greatly the pressure already within the boiler. Whoever has observed a large mass of wrought iron, when plunged at a high heat into twice or three times its weight of cold water, must have remarked how small a quantity of steam was disengaged. There is reason to believe that just as much and no more steam would be produced if the same weight of iron, heated to the same degree, were disposed in the form of a boiler, and the same quantity of cold water were suddenly thrown into it. If, however, the boiler already contained a considerable quantity of water, heated to from 212 deg. to 400 deg., the injection of additional water, upon any overheated surface of the furnace might be followed, as indeed, in such cases, it often is, by an explosion. The effects produced upon the sudden liberation of a great quantity of heat, stored up, under considerable pressure, in the water contained in a steam boiler, will be considered in another part of the present paper. But there is, I think, sufficient reason to believe that an empty boiler, however much it may be overheated, may be filled, or partly filled, with water with no danger whatever of explosion. Red-hot boilers, I am told, have been occasionally filled in this way without any disturbance or consequences of any kind indicating a tendency to explosion. I have never tried such an experiment myself, nor can I, perhaps, furnish such authority as would, by itself, be sufficient to establish such a fact;* but a brief consideration of some of the phenomena of heat has convinced me that it is a fact. The actual quantity of heat which the thin metallic sides of a steam boiler are capable of containing, is not sufficient to change a very large quantity of water into steam. According to the best authorities, the amount or total quantity of heat which would raise the temperature of one hundredweight (112 lbs.) of iron, through one degree, would impart the same additional temperature to 12½ lbs. only of water. The quantity of heat which would raise the temperature of one hunredweight of copper through one degree would raise that of 10⅔ lbs. only of water to the same extent. Thus, if we suppose a locomotive boiler to have 500 lbs. of its copper plates heated to 1,300 deg. (the melting point of copper being 2,160 deg.), this heat would be sufficient only to convert about 50 lbs. of water, already heated under the working pressure to 350 deg., into steam; the water being thrown up, we may suppose, by violent ebullition, as when the communication between the boiler and the steam-cylinder of the engine is suddenly opened. The total heat of steam is a little more than 1,200 deg., although its sensible temperature, to which the copper plates would be cooled in evaporating the water, is 414 deg. only at 275 lbs. pressure, which pressure would correspond very nearly with the density of 50 lbs. weight of steam when compressed into a steam-chamber of a capacity of 80 cubic feet, as in the larger class of locomotive boilers. And it must be understood that the whole quantity of disposable heat, as assumed above, must be appropriated by only 50 lbs. of water (assuming its temperature as 350 deg.), in order that it may be converted entirely into steam. If this quantity of heat be distributed throughout a greater quantity of water, less than 50 lbs. of steam will be produced, inasmuch as a portion of the heat which would be necessary to produce it will have been absorbed in raising the temperature of the additional water, but without raising it into steam. It is plain enough that the quantity of heat which would be sufficient only to raise 50 lbs. of water into steam, would not suffice for converting any greater quantity of water, of the same temperature, into steam, and hence, with the quantities now assumed, 50 lbs. weight of steam could be produced only by the entire appropriation of the disposable heat, in the overheated plates, by 50 lbs. of water, and by the complete exclusion of this heat from any additional quantity of water admitted at the same time. If, therefore, the heat of 500 lbs. of copper plates at 1,300 deg. of temperature, were so far communicated to 50 lbs. of water of 350 deg. as to raise it into steam of 275 lbs. pressure and 414 deg. temperature—the plates being cooled to the same temperature—the strain, might, no doubt (added as it would be to the pressure of steam existing in the

* A letter appeared in "The Engineer" of April 3d, 1857, signed "James Johnstone," and containing the following statement:—"In the course of my investigations I have obtained information that will be of use to your correspondent, 'J. H., jun.,' who, I perceive by your last number, is about to fill a red-hot boiler with water by way of experiment. That has been done, and the result surprised the witnesses. The boiler was 25 ft. long, 6 ft. diameter, and the safety-valve loaded to 60 lbs. per sq. in. When empty and red-hot the feed was let on and the boiler filled up. No explosion occurred, but the sudden contraction of the overheated iron caused the water to pour out in streams at every seam and rivet as far up as the fire-mark extended." In an editorial article which appeared in the "Scientific American" sometime in 1859, a similar experiment attended by the same results, was also mentioned.

boiler before the admission of the water), burst it with all the violent effects of explosion. If, however, the situation of the overheated surfaces was such that a comparatively large quantity of cold water had to be admitted in order to cover a given area of hot metal, so that, by the time the 500 lbs. of copper were covered, 500 lbs. of cold water had been brought into contact with it, no steam could be formed, and the water would be raised by but about 100 deg. of temperature. Any considerable quantity of water being present, its circulation would be so rapid that the heat applied to it at the bottom would be almost instantly communicated throughout its whole mass. This deduction from the accepted laws of heat is borne out, experimentally, in plunging any weight of highly-heated metal into an equal weight of cold water. After the metal has ben cooled to the temperature of the water, little or no evaporation of the latter will be found to have taken place. A pint claret-bottle, the glass of which is by no means strong, may, when filled with cold water, be safely held in the hand whilst a red-hot poker, as large as can enter the neck of the bottle, is plunged into the water. Not only will there be no explosion, but after the poker has been cooled to the temperature of the water, the latter, when shaken up, will have hardly more than a blood-heat, and none of the water will be evaporated. If the hot iron be kept from actual contact with the glass, this simple experiment may be repeated at pleasure without even cracking the bottle.

Much has been said of the spheroidal state of water when thrown upon heated plates. It would appear that, if ebullition were delayed in such case until after a considerable quantity of water had been admitted, the heat of the plate would be so far absorbed in an equal or greater weight of water, that no explosion of the latter into steam could occur. This suggestion is given for what it is worth; but to my mind the spheroidal condition of water, under the circumstances mentioned, has long been an argument against, rather than in favor of, the probability of explosion.

When, however, the plates of a steam-boiler are burnt, the steam which may be in contact with them becomes superheated. Dr. Alban, in his work on the high-pressure engine, mentions that, in his practice, he often found tin-soldered joints in the steam-pipe melted by overheated steam. Jacob Perkins heated steam, out of contact with water, to extraordinary temperatures, and it was his theory that, steam being similarly superheated when the water in a boiler is low, the subsequent agitation of the water, from any cause, instantly produces a large additional quantity of steam, and sufficient to cause explosion. In regard to the degree to which steam may be superheated, Mr. Longridge has mentioned a case in his experience, a few years since, as Chief Inspector to the Manchester Boiler Association. In a boiler on which the steam-gauge marked a pressure of only 10 lbs. per square inch, the steam, held in contact with an overheated plate, became so highly superheated as to completely char the wooden lagging of the boiler, although the wood was entirely removed from any portion of the heating surfaces of the furnaces or flues. In a paper on the subject, read at the Institution of Civil Engineers in 1856, Perkins' theory of boiler explosions was reiterated at some length, and the writer (Mr. W. Kemble Hall) assumed that ordinary steam, superheated to say 435 deg., would instantly convert water, thrown among it, into steam of a pressure of 360 lbs. per square inch. The fact was overlooked, no doubt, that 75 cubic ft. of steam, at a pressure of 140 lbs. per square inch, weigh but 26 lbs., and that the specific heat of steam, at ordinary temperatures, is less than one-third that of water. Thus all the heat contained in 26 lbs. of steam, in a locomotive boiler, supposing the steam superheated even to 350 deg. above the temperature due to its pressure, could not generate much more than 3 lbs. of additional steam, which weight of steam, in the boiler in question, would not raise the pressure, at 140 lbs., to more than 160 lbs. to the square inch. Without pretending to any exactness in these figures, it is apparent upon a little consideration, that the conversion of water into steam, by being thrown up in a divided state, into highly superheated steam, can hardly ever be sufficient of itself to account for any boiler explosion.* Dr. Alban has stated that in some of his experiments with a steam-generator, he stopped the injection of water and kept the enclosed steam in contact with a metal-

* In the Repertory of Patent Inventions, Supplement, January, 1832, page 424, Mr. Thomas Earle gave the results of a calculation similar to the above, and tending to disprove Perkins' theory, at that time being urged.

lic surface at a temperature of 800 deg., and yet no symptoms of an explosion appeared when the water was re-introduced. He adds that a long-continued injection was necessary before enough pressure could be obtained to set the engine at work again.

It is, nevertheless, a favorite opinion with many engineers that the presence of highly superheated steam within a boiler is sufficient to account for the most violent explosion. As compared with other current explanations of boiler explosions, it is perhaps no disadvantage to the explanation by superheated steam that it is incapable of proof. Although any one may blow up a boiler, no one has been able to prove, either by experiment or by calculation, that superheated steam, decomposed steam, or even electricity, could produce such a result. If, on the other hand, we proceed to investigate the properties of steam, under various conditions, with such aids as science has placed at our disposal, we may satisfy ourselves that the explanations in question are erroneous; and it is quite capable of proof by experiment that they are so. It is evident enough that no heat can be generated within the steam or water-chamber of a boiler. All the heat which may exist there must have been communicated from an external source—that is to say, from the fuel burning in the furnace. Heat acts by its quantity, just the same as ponderable matter; and, so far as its effects are concerned, heat is as measurable as a solid body. If we cannot conceive the material existence of heat, we may observe, by the simplest experiment—that of plunging a hot poker into a pail of water—that a given weight of metal, heated to a given incandescence, will always impart a definite, and the same elevation of temperature to a given weight of the cooling or absorbing medium. The quantity of heat which will raise a pound of water through 1 deg. of temperature is as definite and invariable as the quantity of water which will fill a given space, or as the weight, at any height of the barometer, of the air we breathe.

No one, perhaps, would deny these well-known truths in the abstract, and I must plead, as my excuse for repeating them, the general oversight of such facts in the explanation of boiler explosions by superheated steam. Although the sum of the sensible and latent heat of ordinary steam is not constant at all pressures, it is nearly so. Practically, steam not superheated cannot lose any part of its heat without being more or less condensed. In other words, it cannot make an additional quantity of steam; since, to do so, it would require to possess the power of producing and communicating an amount of heat which it did not previously contain. Steam may be led from one vessel and made to boil water in another, but this is only a transference of steam, as all the steam formed in the second vessel will disappear from the first, and as much more besides as was required to raise the water in the second to the boiling point. With ordinary steam, the injection of any quantity of water, cooler than itself, among it, is attended with a partial condensation of the steam, and the elevation of the temperature of the water, but never by the production of additional steam. The quantity of heat which will raise 1 lb. of water through 1 deg. being termed an "unit of heat," about 1,150 units will be required to convert 1 lb. of water, at 60 deg., into steam. But if the heat for conversion come from superheated steam (and it must be superheated, in order to generate additional steam, since it can part with none of its ordinary or normal heat without more or less condensation), we then find that, owing to the difference between the specific heat of steam and that of water, a pound of the former must be superheated by nearly 3,500 deg., in order to impart 1,150 units of heat to a pound of the latter; at the same time maintaining its own existence as steam. Considering that an ordinary locomotive boiler seldom contains 25 lbs. of steam, disengaged from the water, and that even 1,000 deg. of superheating in addition to from 300 deg. to 350 deg., the ordinary temperature of the steam, would be excessive, the explanation by superheated steam appears sufficiently incomplete to warrant its rejection.

The foregoing reasoning upon the production of steam from water thrown upon red-hot plates was first suggested to me by Mr. D. K. Clark; although I understand Mr. Clark to hold the opinion that the steam thus produced cannot be sufficient to account for boiler explosions. Under certain circumstances, I believe a boiler may be violently exploded by the steam thus formed, and I think the explanation by overheating possesses considerable probability, although it cannot, of course, be adopted in those frequent cases where there

is proof that no overheating has taken place.

ELECTRICITY.

The well-known fact that steam sometimes exhibits electrical properties on being discharged into the air, no doubt suggested the electrical hypothesis of boiler explosions. Those, however, who have adopted this hypothesis are unable to furnish any evidence of the existence of free electricity within a steam boiler. All our knowledge of electricity goes to show that even if it were developed by ebullition, or in steam when confined under pressure, it could not collect within a metallic vessel, which, like a boiler, is in perfect electrical communication with the earth. The electrical phenomena sometimes observed when steam is being discharged into the air are believed to be caused partly by the friction of the escaping steam upon the inner surfaces of the discharging channel; whilst it is possible that electricity is also liberated in the condensation of steam in the open air.

Professor Faraday has examined with great care the action of Armstrong's hydro-electric engine,* in which steam, generated from distilled water in a boiler insulated upon glass supports, produces electricity on being discharged through a peculiar apparatus into the air. The steam is led by a pipe from the boiler, and through three or more small passages surrounded with a cooling apparatus, by which the steam is partially condensed into drops of water. In this state it enters, by tortuous passages, a series of discharging nozzles, each of which has an internal bushing or lining of box-wood. On the final discharge of the steam from these nozzles into the air, electricity is disengaged, and is collected by suitable metallic points connected with an ordinary conductor. Although powerful discharges can be thus obtained, there is no evidence whatever of the presence of electricity within the boiler. Indeed it is only by certain very peculiar arrangements that electricity is obtained at all. Professor Faraday found that if, instead of distilled water, ordinary spring water, containing the usual proportion of atmospheric air, was employed; or, if any saline, acid, or alkaline substance capable of acting as a conductor, was dissolved in the water in the boiler, there was no electricity to be had. Nor did the conductor become charged unless the process of partial condensation was maintained in the "refrigerating box;" and, what was more singular, nothing but *box-wood* nozzles appeared to have the power of finally exciting the electrical action at the instant of discharge.

The results of Professor Faraday's researches, as to the mode in which electricity was produced in the experiments which he made with Armstrong's machine, comprise the following facts:—

1. The production of electricity is not due to any change in the state of the liquid contained in the boiler.

2. A current of dry steam produces no development of electricity. The production of electricity is due to the friction in the box-wood nozzle of the drops of water, formed by the partial condensation of the steam in the refrigerating box.

3. Increasing the pressure of the steam increased the development of electricity by increasing the friction of the issuing jets of steam and water.

4. The same results were obtained from compressed air, discharged through the box-wood nozzles, as from steam discharged under the same circumstances. When the air was perfectly dry there was no development of electricity; when the air was humid, and contained besides a very little pulverulent matter, the friction of discharge produced electricity in the same manner as when steam was employed in the experiments.

It will be borne in mind that with all the special and peculiar conditions requisite for the production of electricity by this apparatus, the boiler must be perfectly insulated on glass supports. And although Mr. Armstrong probably constructed his machine under the impression that the generation of steam was essential to the results sought to be obtained, Professor Faraday found that the same results were disclosed when atmospheric air, condensed to the same pressure as the steam, was employed in its stead.

It has been ingeniously argued that steam boilers may become insulated by an internal coating of boiler-scale. It would be necessary, however, that this scale should completely cover every part of the internal surfaces of the boiler, and even those of the steam pipe, stopcock, etc. A

*The hydro-electric engine in the "Conservatoire des Arts et Métiers," at Paris, is the only one of the kind that I have seen, and I have taken the results of Professor Faraday's examination of the machine from Gavarret's "Traité d'Electricite," Paris, 1857.—Z. C.

single crack in any part of this complete dielectric lining would liberate any electricity which might be contained in the steam. Whilst there is no probability that any steam boiler was ever so completely lined with scale, there is another fact which appears to dispose of the electrical explanation, even if perfect insulation existed. This fact is, that water may be boiled in a perfect Leyden arrangement with no development of electricity.

Without pursuing the electrical hypothesis any further, we may observe that no one has yet offered to explain how electricity, even if it existed in high tension, would explode a steam boiler. And, if it exist at all in steam boilers, why does it not exist in all boilers? And if in all, why does it not manifest its presence in other ways than in explosions? If electricity act at all it must be by quantity, and if the quantity developed be sometimes sufficient to burst boilers, we have a right to look for visible, although milder, phenomena when the quantity is insufficient. Yet no phenomena of the kind, sufficient to excite alarm, or even to attract attention, are observed. The fact is, no one has elaborated the electrical hypothesis into anything like a theory of boiler explosions. The presence of electricity has been suggested, and among those who prefer mystery, or, at least, very obscure explanations, to circumstantial investigation, some have referred boiler explosions to electricity.

DECOMPOSED STEAM.

The unsatisfactory results generally obtained by those who have sought to decompose water by heat, on a large scale, with the view of applying its elementary gases separately, does not appear to have prevented the occasional adoption of the hypothesis that, in certain cases, all the steam contained within a boiler is decomposed, and its hydrogen (by some means not easily explained) exploded with great violence. That steam, passed over pure metallic iron heated to redness, is decomposed is perfectly true, although the iron must retain all the oxygen separated in the operation. With oxidised iron, however, the process of decomposition cannot be continued. This is, I believe, a chemical fact of which there can be no dispute. To decompose 1 lb. of water (or steam, which is chemically the same substance), 14.2 oz. of oxygen must be fixed by the iron, and only 1.8 oz. of hydrogen will be set free. This large proportion of oxygen, absorbed by only a few square feet of overheated surfaces, would soon form an oxide of iron of sufficient thickness to arrest all further decomposition, and all the hydrogen up to that time disengaged would not amount, perhaps, to 1 lb. in weight. By itself, or mixed with steam, hydrogen cannot be exploded, nor even ignited. It will extinguish flame as effectually as would water.

Upon this subject, I may refer to a report made by Professor Faraday in May, 1859, to the Board of Trade, upon the liability to accident consequent upon the introduction of an apparatus for superheating steam on board the Woolwich steamboats. In this apparatus the steam was carried, in iron pipes, immediately through the furnace and in contact with the incandescent fuel. Professor Faraday, after having examined the apparatus at work, says:—

"I am of opinion that all is safe, *i. e.*, that as respects the decomposition of the steam by the heated iron of the tube, and the separation of hydrogen, no new danger is incurred. Under extreme circumstances the hydrogen which could be evolved would be very small in quantity—would not exert greater expansive force than the steam—would not with steam form an explosive mixture—would not be able to burn with explosion, and probably not at all if it, with the steam, escaped through an aperture into the air, or even into the fire-place.

"Supposing the tubes were frequently heated over much, a slow oxidation of the iron might continue to go on within; this would be accompanied by a more rapid oxidation of the exterior iron surface, and the two causes would combine to the gradual injury of the tube. But that would be an effect coming under the cognizance of the engineer, and would require repair in the ordinary way. I do not consider even this action likely to occur in any serious degree. I examined a tube which had been used many months which did not show the effect; and no harm or danger to the public could happen from such a cause."

Professor Taylor, of Guy's Hospital, reported in part, as follows, upon the same apparatus:—

"It is true that steam passed over pure metallic iron heated to redness (1,000 deg.), is so decomposed that the oxygen is fixed by the iron while

hydrogen gas is liberated. This chemical action, however, is of a very limited kind. The surface of the iron is rapidly covered with a fixed and impermeable layer of the magnetic oxide of iron, and thenceforth the chemical action is completely arrested. If the interior of an iron pipe has been already oxidized, by passing through it, while in a heated state, a current of air, there will be no decomposition of steam during its passage through it. If the interior of an iron pipe were not thus previously oxidized, it would speedily become so by the oxygen derived from the air, which is always mixed with steam. Hence, chemically speaking, under no circumstances, in my opinion, would any danger attend the process of superheating steam, as it is conducted under this patent.

"It is proper also to state, that hydrogen is not explosive, but simply combustible, and assuming that it was liberated as a result of the decomposition of superheated steam, its property of combustibility would not be manifested in the midst of the enormous quantity of aqueous vapor liberated with it and condensed around it. There could be no explosion, inasmuch as hydrogen, unless previously mixed with oxygen, does not explode; and oxygen is not liberated; but actually fixed by the iron in this process. It is a demonstrable fact that the vapor and gas evolved under the form of superheated steam, tend to extinguish flame and to prevent combustion from any other cause."

Professor Brande, in a report made by him to the patentees of the same apparatus, observes:—

"In reference to the question which you have submitted to me, respecting the possible or probable evolution of hydrogen gas and consequent risk of explosion in the processes and by means of the apparatus which you employ for the production of superheated steam, I am of opinion that there can be no danger from such effect; that the temperature to which the iron pipes connected with your boiler are raised, and the extent of the iron surface over which the steam passes, are insufficient for its decomposition; and that if the temperature of the pipes were even raised considerably beyond that which you employ, or would be able to attain, a superficial layer of oxide of iron would line the interior of the heated pipes, and so prevent any continuous decomposition of water. Effectually to decompose steam, by passing it over iron, it is necessary that a very extended surface of the metal (as in the form of thin plates or iron turnings) should be used, and that the temperature should be continuously maintained at a bright red heat, namely at a temperature considerably above 1,000 deg. of Fahrenheit.

"I have read Dr. Taylor's report, and entirely agree with the inferences he has drawn as to the absence of danger from the evolution of hydrogen gas in practically carrying out your process for the production and application of superheated steam."

The practical conclusions upon this subject are the following:—1. Decomposition cannot possibly occur, to any considerable extent, under any circumstances arising in the working of ordinary steam-boilers; 2, If it did occur, the hydrogen thus liberated would have no access to oxygen, without which it could neither inflame nor explode; 3, Even if oxygen were present, the presence of steam would prevent ignition; and, 4, If oxygen were present, and no steam existed in the boiler, the hydrogen would only inflame and burn silently as fast as it was produced, the heat for ignition being supposed to come from a red-hot plate. Under these accumulated impossibilities of violent explosive action, the explanation of boiler explosions by the decomposition of steam is without any support whatever.

OVERPRESSURE.

Any pressure, whether gradually or momentarily generated in a boiler, is an overpressure when it exceeds the safe working pressure; and, strictly speaking, there must always be overpressure whenever a boiler is burst. When, however, an explosion is said to have occurred by overpressure, it is commonly understood that the pressure has been allowed to increase gradually up to the limit of the strength of the boiler, and if this has been calculated to correspond to a pressure of 700 lbs., for instance per square inch, the actual pressure at the moment of explosion is accordingly assumed at that moment. Boilers may, perhaps, be generally capable of withstanding nearly their full calculated bursting pressures; indeed, comparatively few boilers do fail in any way, for after all, the number of explosions—numerous as they are—bears but a very small proportion to the actual number of boilers in use. But for the purposes of investigation, there are abundant instan-

ces of the quiet rupture of steam boilers under ordinary working pressures, so that even a violent explosion does not absolutely prove that the pressure under which it occurred was anything like the calculated bursting pressure of the boiler. If the bursting pressure be 758 lbs. per square inch it might not be difficult to raise the steam to that point and burst the boiler. Yet it is very improbable that anything like a pressure of 758 lbs. per square inch ever accumulates in a boiler intended to work at 100 lbs. or 125 lbs. We will suppose a locomotive boiler with 75 cubic ft. of water room containing 4,650 lbs of water, and 75 cubic ft. of steam room containing 23 lbs. in weight of steam at a pressure of 120 lbs. per square inch. To increase the pressure even to 285 lbs. per square inch, $25\frac{2}{3}$ lbs. additional weight of steam would have to be compressed into the steam-chamber, and the remaining $4{,}624\frac{1}{3}$ lbs. of water would have to be raised to 350 deg., the temperature of steam of 120 lbs. to $417\frac{1}{2}$ deg., the temperature of steam of 285 lbs. pressure. The $25\frac{2}{3}$ lbs. of additional steam, formed from water of an average temperature of 380 deg., would have absorbed about 21,000 units of heat, whilst the elevation of the temperature of 4,624 lbs. of water, by $67\frac{1}{2}$ deg., would require 312,120 units of heat. The whole heat thus expended would equal that necessary for the evaporation of about 285 lbs. of water under a moderate pressure, and this heat would require the combustion of at least 32 lbs. of good coke. Although the steam gauge of a locomotive will often rise 7 lbs. or 8 lbs. a minute in standing, and 10 lbs. or even 15 lbs. when a strong blast is turned up the chimney when running with a light load, the steam could not probably rise from 120 lbs. to 285 lbs. in much less than twenty minutes under any circumstances likely to occur in practice. Mr. Fairbairn has calculated that with a certain locomotive boiler on which he experimented, 43 minutes would be required to raise the pressure from that of the atmosphere to 240 lbs. With the same boiler under the same circumstances as in the first experiment, 28 minutes would be required to raise the pressure from 60 lbs. to 300 lbs. per square inch. The rapidity with which the steam pressure would rise would altogether depend upon the relative extent and temperature of the heating surface to the quantity of water in contact with it. Mr. Martin Benson who has had much experience in the working of the steam fire-engines employed at Cincinnati, United States, informs me that, with the fires carefully laid with light combustible materials, steam has been raised in the boilers of these engines in 4 min. 38 sec., from cold water to a pressure of 65 lbs. per sq. in. In 2 min. the pressure has been raised from 10 lbs. to 90 lbs. per sq. in. In these boilers, however, the tubes are first heated, and small quantities of water are afterwards injected into them, the whole quantity of water at any time in the boiler rarely exceeding one cubic foot.

The simple increase of pressure in a boiler, either when at work or when standing, must undoubtedly be comparatively gradual—a matter of some minutes, at least. Whatever might cause the steam gauge to mount, suddenly, from 100 lbs. to the limit to which it is marked, it is very certain that the necessarily gradual increase of the heat of the water within the boiler could not produce such a result. Yet those who have given any attention to the subject of boiler explosions are aware that they frequently occur when, without any overheating of the plates, the pressure stood, but a moment before, at the ordinary working point. In the case of the locomotive boiler which exploded in the summer of 1858, at Messrs. Sharp, Stewart & Co.'s, at Manchester, the pressure, as observed upon two spring balances and a pressure-gauge, stood at 117 lbs. to 118 lbs., a minute before the explosion, both valves blowing off freely at the time. The part of the boiler which exploded was the ring of plates next the smoke-box, out of the influence of any part of the fire. The fact, therefore, of the violent explosion of a strongly made boiler at 117 lbs., is a proof that it is not necessary to assume and to account for the existence of any pressure about that point. On the 5th of May, 1851, a locomotive engine, only just finished, burst its boiler in the workshop of Messrs. Rogers, Ketchum & Grosvenor, at Paterson, New Jersey, United States. I was upon the spot but a few moments afterwards, and found the effects of the explosion to be of the most frightful character: a consider able portion of the three-story workshop being blown down, whilst four men were instantly killed, and a number of others were injured, one of whom died soon afterwards. Several of

the men, who, although immediately about the engine at the time, escaped unhurt, unanimously declared that the safety-valves were blowing off before the explosion, and that the two spring balances indicated, but a moment before the crash, a pressure of but 110 lbs. per sq. in. On the 12th of February, 1856, the locomotive Wauregan exploded, after standing for upwards of two hours in the engine-house of the Hartford, Providence, and Fishkill Railroad, at Providence, United States. Only sufficient steam had been maintained in the boiler to enable the engine to be run out of the house; but at the time of the explosion the engine had not been started, the engine-man, who was killed, being upon the floor, at the side of the engine, at the time. The boiler gave out in the ring of plates next behind the smoke-box. Destructive explosions often occur at pressures of 10 lbs. to 12 lbs. per sq. in. in low-pressure boilers; and it is on many accounts improbable that anything like the calculated bursting pressures of boilers is ever reached, even where the most frightful explosions have occurred. Not only would the accumulation of steam of the calculated bursting pressure require considerable time, but the gauge, if there were one, would soon be fixed at the limit of its motion, and the safety-valves, if they were not wedged down, would blow off with unusual violence. In the case of locomotive engines, which have no self-acting governors, any considerable increase of pressure would, if the engine were under way, quicken its speed, and cause the driving wheels to slip upon the rails to such an extent as to arrest the attention of the engine-man. The fact that he would have to nearly close the regulator, and keep it nearly closed, whilst drawing a load with which it was at other times necessary to run with the regulator wide open, would be a significant indication of the state of things in the boiler.

If boilers burst only from overpressure, they would, of course, give out first—as, indeed, they always must—in the weakest part; say, along a seam of rivets, which is but about one half as strong as the solid plate. But, after one seam had opened, the relief of pressure would be so instantaneous that, without subsequent percussive action, the rupture could hardly extend itself through solid plates of nearly twice, or even, perhaps, ten times the strength of the part which first gave way. The general strength of the solid plates of a boiler should be, and probably is, from ten to twenty times greater than that of any part so weak as to rupture, as is often the case, under the ordinary working pressure. Mr. Whitworth has made an experiment upon one of his new cannon, made of homogeneous iron, which shows how a great pressure may relieve itself by a very small opening. After loading one of his 3-pounders, he plugged the muzzle so as to render it impossible for the gun to discharge itself in the ordinary manner. On firing the charge the piece did not burst, but all the gases escaped through the "touch-hole." This severe test was repeated several times. In the case of excessive pressure, there would be many circumstances to attract the attention of the attendants, whereas explosions more commonly occur with little or no warning whatever.

This line of argument tends, undoubtedly, to assimilate the conditions of violent explosion to those of quiet rupture; and although like causes should produce like effects, it may perhaps be shown that, so far as pressure alone is concerned, either explosion or simple rupture may occur indifferently at one and the same actual pressure, existing up to the moment of failure. Instead, therefore, of calculating the strength of a boiler from its diameter and the thickness of the plates, and then assuming that it can only burst at a corresponding pressure, I shall adopt the fact of quiet or simple ruptures as proving (what might, indeed, be taken for granted) that boilers are not always as strong as they are calculated to be; and I shall then endeavor to show how violent explosion may result in one case from a pressure which only causes quiet rupture in another.

Overheating, which has been considered with reference only to the generation of steam from water suddenly thrown on heated plates, and with reference to the decomposition of steam, may materially reduce the strength of boiler plates. Up to temperatures of 400 deg. and 550 deg. boiler plates have not been found to be weakened; indeed, the experiments of the Committee of the Franklin Institute indicated a gradual gain of strength, with increasing temperatures, up to a certain point, and that the strength at 550 deg. was equal to that at 55 deg. Mr. Fairbairn finds the strength diminished one-fourth at

a red heat; and it is not difficult to understand that, at a very high heat, no reliance whatever could be placed upon iron or copper when subjected to strain. The furnace-flues of Cornish boilers, and the crown-plates of locomotive boilers, frequently alter their shape when overheated, and are often continued in regular work, until from some cause—another burning, perhaps—they give out entirely. Although an examination of the furnace-plates, recovered from an explosion, often shows that they have never been subjected to an injurious temperature, overheating must be taken as one among the various causes which may operate to weaken a steam boiler.

Again, as it is considered injurious to a boiler to prove its strength, before it is put under steam, by a great hydrostatic pressure, we have no better means of ascertaining its actual strength than by inferring the bursting pressure from its dimensions, and from the thickness and general quality of the plates. Indeed, the actual strength of a boiler can be ascertained only by a process which involves its destruction. In other words, pressure of some kind must be accumulated within it until it bursts, in order to know what amount of pressure will suffice to burst it. A new locomotive boiler, of peculiar construction, which exploded in October, 1856, at Messrs. Bolckow & Vaughan's ironworks, at Middlesborough-on-Tees, was believed to have been injured in a previous test, by steam pressure of 130 lbs. per sq. in. Dr. Joule, of Manchester, has lately called attention to the liability to injury to which boilers are exposed under tests by steam or hydrostatic pressure. He proposes a test employed by himself with entire success for the last two years. He fills the boiler entirely full of water, and then makes a brisk fire upon the grate. When the water has been warmed to from 70 deg. to 90 deg., the safety-valve is loaded to the pressure up to which the boiler is to be tested. The rise of pressure is then carefully observed by a steam pressure gauge; and if the progress of the pointer be constant and uniform, without stoppage or retardation, up to the testing pressure, it is inferred that the boiler has withstood it without strain or incipient rupture. In this mode of testing, the expansion of the water, by heat, is so rapid, that Dr. Joule has found the pressure to rise from zero to 62 lbs. per sq. in. in five minutes. But this mode of testing the strength of a boiler cannot, any more than any other mode, show the strength beyond the testing pressure; it cannot show the actual strength or bursting pressure of the boiler except that be destroyed in the test. And although the quality of the materials and workmanship in steam boilers may vary generally within narrow limits only, not only different boilers, but different parts also of the same boiler, are of very unequal strength. The weakest part of the weakest boiler may be almost immeasurably weaker than the strongest part of the strongest boiler. The material of which boilers are made varies greatly in strength. In Messrs. R. Napier & Sons' recent experiments (conducted by Mr. David Kirkaldy) upon the strength of iron and steel, one sample of Farnley plate iron bore a strain of 62,544 lbs. per sq. in., whilst another sample of iron from the same makers broke under a strain of 40,541 lbs. per sq. in. Glasgow ship-plates bore, in one case, 53,370 lbs. per sq. in. and in another only 32,440 lbs. Even Lowmoor iron varied in strength between the limits of 47,426 lbs. and 57,881 lbs. per sq. in. However the strength of iron may be averaged for the general purposes of the engineer, we are never justified in assuming an average or standard strength for the particular parts of a steam boiler which, in the case of explosion, were the first to give out. The fact of explosion is in itself *prima facie* evidence that these parts were not of average strength, and affords good ground for the presumption that they were of only the minimum strength; and the minimum strength of iron is not known, for however weak a given specimen might be, another one, much weaker, might doubtless be found. Comparatively, few experiments have ever been made upon the strength of plates, and the averages given by Mr. Fairbairn and others have been taken from comparatively few trials. Messrs. Napier's experiments were considered very comprehensive; yet they included only 150 sepecimens of iron plates, with which number the range of strength was from 32,450 lbs. to 62,544 lbs. per square inch. Mr. Fairbairn found the strength of a broken plate, taken from the boiler which exploded at Messrs. Sharp, Stewart & Co.'s, to be only 4.66 tons per square inch, or but one-fifth of the proper average. It is presumable, perhaps, that the strength of plate iron varies within as wide limits as that of cast iron, from which plate

iron is made, and upon the quality of which its own must also depend. The Government cast iron experiments concluded last summer, at Woolwich, comprised 850 specimens, ranging in strength from 9,417 lbs. to 34,279 lbs. per square inch, the average strength of all the specimens being 23,257 lbs. It must be remembered, however, that the sample which bore only 9,417 lbs. per square inch cannot be taken as the weakest which would occur in practice, inasmuch as it was not selected at random from iron in the market, but was one of several samples which had been contributed by a long-established firm, with the expectation, no doubt, of obtaining the preference of the authorities. If the poorest iron were purposely sought for, as it should be, in order to estimate the chances of failure, cast iron could, no doubt, be found which would not bear a strain of 3,000 lbs. per square inch; whilst, on the other hand, there are authenticated instances of tests in which cast iron did not yield until the strain had reached 45,000 lbs. per square inch.

Apart, also, from the quality of the iron, its thickness varies greatly in the practice of various makers. In the United States, for example, the plates in the waist of a locomotive boiler, 48 in. in diameter, and intended to carry steam of 120 lbs. per square inch (sometimes increased to 160 lbs. or more), are $\frac{1}{4}$ in. only, although $\frac{5}{16}$ in. plates are occasionally used. In England, the thickness of plates for such a boiler is from $\frac{3}{8}$ in. to $\frac{1}{2}$ in.; $\frac{7}{16}$ in. being a common thickness. In France a 48-in. locomotive boiler, the pressure within which rarely exceeds 120 lbs., is generally 15 millimetres, or $\frac{6}{10}$ in. thick. The strongest form of a boiler is a homogeneous metal tube, drawn solid, and of from say $1\frac{1}{2}$ in. to 2 in. diameter. Its bursting pressure is seldom less than 7,000 lbs. per square inch; in some cases, as much as 15,000 lbs.

In working iron into steam-boilers, it is commonly supposed that the loss of strength in punching is proportional only to the width punched out. If, in a row of rivet holes, in the edge of a plate 24 in. wide, there are 13 holes of $\frac{3}{4}$ in. diameter, the length of iron removed in the line of strain is $13 \times \frac{3}{4} = 9\frac{3}{4}$ sq. in., or but about two-fifths of the whole width of the plate. Mr. Fairbairn has found, however, that the strengh of a given section of plate iron, as left, after punching, between two rivet holes, is actually less than the strength of an equal section of the same plate before punching. In eight experiments, the highest strength of the plate experimented upon was 61,579 lbs., and the lowest 43,805 lbs., per sq. in., the average of the whole being 52,486 lbs. per sq. in. But with the same plate, after punching, the strength per square inch of the metal left between the holes varied between only 45,743 lbs. and 36,606 lbs., the average of seven tests giving only 41,590 lbs. per sq. in. of the remaining solid iron, against 52,486 lbs., the strength of the same section of the same iron before punching. With this injury, therefore, in punching the iron, by which even the remaining solid iron is weakened by more than one-fifth, the strength of an ordinary single riveted seam is, as was many years ago ascertained by Mr. Fairbairn, only 56 per cent., or a little more than one-half that of the same plate tested through solid iron away from the seam. Single riveting alone, therefore, destroys, upon the average, 44 per cent. of the strength of the weakest plate worked into a steam boiler. In some cases, the injury by punching may be much greater than was apparent in Mr. Fairbairn's experiments. I have seen, in one of the most extensive engine works in France, punched plates of iron, $\frac{6}{10}$ths in. thick, in which there were cracks from three consecutive rivet holes to the outer edge of the plate. As sometimes made up (and in dealing with boiler explosions it is our business to look for extreme cases), the plates are got together by the aid of "drifts," and the iron is under a greater or less initial strain before steam is ever raised in the boiler.

Apart from the quality of the materials, and from the effects resulting from the ordinary processes of securing them together, the general construction of a steam boiler greatly affects its strength. In Mr. Fairbairn's experiments upon the stayed sides of locomotive fire-boxes, a plate-iron box, made to represent the side of a strongly stayed fire-box, bore, in one case, the enormous pressure of 1,625 lbs. yer sq. in. before yielding. The strength of the sides of a locomotive fire-box depends, however, almost entirely upon the stay-bolts alone, as without these the sides of the fire-box would be the weakest parts of the whole boiler. Yet I have frequently found these stays (where made of wrought iron) to be

as brittle, after a few years' use, as coarse cast iron. I have broken them off from the sides of old fire-boxes, sometimes with a blow no harder than would be required to crack a peach-stone. The upper stay-bolts appear to suffer the most. Their deterioration, after long use, has been attributed to slight but repeated bendings, caused by the expansion of the fire-box every time the fire is lighted, and its subsequent contraction when the boiler is again cooled. Upon this supposition, some locomotive makers turn these bolts to a smaller diameter in the middle of their lengths than at their ends, with the view of permitting a "spring" without short bending, under the alternating movements of the fire-box.

Mr. Fairbairn's experiments upon the strength of iron tubes have, as is well known, disclosed most important facts bearing upon their relative resistance to internal and external pressure. Until the recent announcement of Mr. Fairbairn's discovery that the resistance of metal tubes to collapse was, within certain limits, inversely as their length, their strength, or, more properly speaking, their weakness, was generally unknown. One startling result, as ascertained from the experiments under notice, was, that, whilst the bursting pressure of a boiler 7 ft. in diameter, 30 ft. long, and composed of single-riveted $\frac{3}{8}$ in. plates, of average quality, was 303 lbs. per sq. in., the collapsing pressure of its 3-ft. internal plain flue of the same thickness of metal, was but little more than 87 lbs. per sq. in., or hardly more than one-fourth that required to burst the shell.

The steam domes of locomotive boilers are sometimes of more than one-half the diameter of the barrel, which is consequently much weakened. It has been observed that locomotive boilers frequently burst through the plates to which the dome is attached, or through the plates immediately adjoining. Locomotive boilers, also, are occasionally, though not often, made of an oval section, their vertical diameter being 3 in. or 4 in. larger than the horizontal diameter. A large number of the locomotives constructed by the late M. Camille Polonceau, at the Ivry workshops of the Paris and Orleans Railway, have oval boilers of this kind. Although such boilers are unquestionably weaker than when made of a truly cylindrical form, there are very few explosions upon the Orleans, or indeed upon any of the French lines. An engine exploded some two years ago at the Corbeil Station of the Orleans Railway.

The employment of angle-iron in the construction of many of the older locomotive boilers involved some danger, and it is doubtful if the real resistance of angle-iron to longitudinal cracking is known at all. In Messrs. Napier's experiments, last summer, four bars of Consett ship angle-iron bore from 43,037 lbs. to 54,962 lbs. per sq. in. when broken by a strain in the direction of their length. The process of manufacturing angle-iron tries it most severely, however (unless the iron be originally of the very best quality), by inducing incipient cracking along its length, giving it a reedy structure, and thus inviting the complete separation of one leaf from the other at the bend. Not a pound of angle-iron has been employed for several years in the construction of American locomotive boilers, and as far as I am aware the French locomotive makers have abandoned its use. All the angular junctions in the outer shells of American locomotive boilers are rounded with an easy curve of seldom less than 4 in. radius. The square corners made in the inside fire-box plates, which are almost always of iron, require the very best quality of metal of a thickness of not more than $\frac{1}{16}$ in., whilst the usual thickness is only $\frac{1}{4}$ in. I have frequently seen what was considered to be a good quality of $\frac{3}{8}$ in. plate cracked completely in two under the attempt to bend it to a square corner.

The defects originally existing in a plate of iron are occasionally discovered after its failure has produced a violent explosion. The freight engine Vulcan, employed upon the Buffalo and Erie Railroad, U. S., burst its boiler with terrific violence in August, 1856. Although the engine was one of three which had been built, as was believed with unusual care, one of the broken plates, afterwards recovered, exhibited a flaw 24 in. long. The plate which first gave way formed a part of the outer fire-box and extended to the dome, the 24 in. opening for which was an additional abstraction from the strength of the structure. The upper part of the fire-box was blown completely off to one side, and the engine was thrown, bodily, 25 ft. to the other side, and into a ditch.

The case of the engine Vulcan illustrates that of many others where explosions have occurred in consequence of a congenital defect, after the boiler had been for a consid-

erable time at work. It would be natural to ask why, if a boiler be originally defective, it does not explode the first time it is brought under steam? How can the final explosion be delayed one, two, or even ten years, when, all along, a hidden flaw, a broken rivet, or a rotten plate existed in the boiler; and whilst explosion, therefore, must have been constantly impending under an almost perfect equilibrium between strain and resistance? Does the strength of the boiler, after it has been completed, deteriorate rapidly by use? Mr. William Shaw, Jr., of the Tow-lane Ironworks, Durham, wrote to "The Engineer" newspaper, under date of 15th December, 1856, stating that, whilst he had 20 high-pressure boilers under his inspection, he had found fibrous iron, after a few years' use, to become crystallized, and as brittle as blister steel. On the other hand, Mr. Samuel J. Hayes, formerly Master of Machinery of the Baltimore and Ohio Railroad, U. S., and now holding a similar appointment upon the Illinois Central Railroad, at Chicago, Ill., U. S., has informed me that he tested some of the plates of a boiler which exploded at Baltimore, in 1852, after 15 years' service, and that the iron bore an average tensile strain of 60,000 lbs. per sq. in. before yielding. It is doubtful if the iron in a steam boiler alters its condition except by over-heating; although certain parts of the boiler may sustain injury from alternate expansion and contraction. Mr. Frederick Braithwaite read a paper, some time ago, before the Institution of Civil Engineers, upon the "Fatigue of Metals," in which paper iron was assumed to lose its strength under long continued strain. I cannot enter here upon the conclusions of the paper in question, but I may refer to an experiment, made, I believe, by Mr. Fairbairn, wherein a cast-iron column was loaded with .97 of its estimated breaking weight, which weight was supported for six months, when the column broke. It is evident enough that a steam boiler, especially a locomotive boiler, is exposed to constant influences tending to weaken it; and, apart from all reasoning under this head, the fact of the frequent quiet rupture of steam boilers, sometimes after several years' steady work, is a sufficient proof that local defects, whether original or produced, may exist for a long time before the actual failure of the defective parts.

With regard generally to failures resulting from an inferior quality of materials or workmanship, or from improper construction or management, it may be said that whereas but one explosion occurred in the year 1859, among the 1,618 boilers under the care of the Manchester Boiler Association, no less than 14 boilers were found to be in a "dangerous" condition, and 100 in an "unsatisfactory" condition from the fracture of plates; at least one boiler out of every fifteen under inspection having exhibited an injury of that kind in a single year. But for the admirable system of boiler-inspection pursued in Manchester (and more recently adopted at Huddersfield), the larger number of these injuries would have remained undiscovered, and instead of one explosion there might have been twenty.

Corrosion sometimes goes on entirely unsuspected. In a boiler which recently exploded at Tipton, considerable breadths of the iron were found to have been reduced in thickness to $\frac{1}{64}$th in. In the case of the explosion of a boiler at the Clyde grain mills, at Glasgow, in April, 1856, extensive breadths of the iron were said to have been reduced to the thickness of a sixpence; and in the disastrous explosion which occurred in August of the same year, at Messrs. Warburton & Holker's, at Bury, the evidence showed that the bottom plates had been reduced for a greater or less width to only $\frac{1}{16}$ in. in thickness. In the year 1859 there were reported 44 cases of "dangerous," and 153 cases of "unsatisfactory" corrosion, among the 1,618 boilers under the inspection of the Manchester Boiler Association. Thus there was nearly one case of corrosion in every eight boilers, in a single year.

All these facts, it will be observed, support the probability of explosion at nearly the ordinary working pressures. And, in the majority of cases, I believe it may be correctly assumed, in the absence of positive evidence to the contrary, that an exploded boiler, although to all appearance perfect up to the moment of rupture, contained some hidden defect. The fact of explosion, except under very peculiar circumstances, appears to be a better evidence of a defect in the boiler than of the previous existence of anything like a calculated bursting pressure of steam; such as 500 lbs. or 600 lbs. in a boiler made to work at 100 lbs. per sq. in.

If, however, boilers of the full calculated

strength have ever been burst by gradually accumulated pressure, it would be the easiest thing possible to prevent the recurrence of such disasters. If one or two safety-valves are sufficient, under ordinary circumstances, to liberate the steam as fast as it may be generated in the boiler, three, four, or, certainly, half-a-dozen equally large safety-valves, all blowing off at just above the ordinary working pressure, and all acting independently of each other, would effectually prevent all chance of overpressure If the explanation by overpressure, so persistently urged by Mr. Fairbairn, be the true explanation, boiler explosions may be entirely prevented, even where the attendants are guilty of the grossest carelessness. For with a sufficient area of effective safety-valve opening, it would be absolutely impossible, under the hardest firing, to raise the pressure 20 lbs. above the point at which the valves had been set to blow off. Safety-valves are simple, and comparatively inexpensive appliances, and they should be so fitted as to leave no doubt of their efficiency. Hawthorn's annular safety-valve, when its area is properly proportioned to the evaporative power of the boiler, renders any accumulation of pressure above the safe working limit quite impossible. Upon the locomotives of some of the Austrian railways, Baillie's 12-in. safety-valves, held down by volute springs pressing directly upon the valve, are in use. In a trial made in Vienna, to ascertain the discharging power of this kind of valve, the fire in a locomotive fire-box was urged by a jet of steam in the chimney, the engine being at rest, and 80 cubic ft., or 2¼ tons, of water were evaporated in one hour and discharged, in the form of steam, from the safety-valve. Although originally loaded to 64 lbs., the valve did not rise, during the experiment, above a point corresponding to a pressure of 76 lbs. per sq. in. The relief of pressure depends entirely upon the extent of safety-valve opening, supposing the valves to be in working order. Since the recent explosion of a locomotive boiler on the Lewes branch of the Brighton Railway, Mr. Craven, the locomotive superintendent, has expressed his intention of applying three safety-valves, of the usual size, to each of his engines. Whilst it would be quite possible, with a boiler unprovided with safety-valves, or of which the valves were inoperative, to produce an explosion by overpressure, it would be equally impossible to do so when these outlets from the boiler were equal in discharging capacity to its evaporative power. The fact of explosion by sheer overpressure is a proof, simply, that the safety-valves were either inoperative or of insufficient size.

EXPLOSION AT ORDINARY PRESSURES.

If an iron cylinder be burst by hydrostatic pressure, the broken parts are not projected into the air. The pressure being relieved by the rupture of the iron, it ceases to act before the ruptured parts can acquire momentum. In the case of a locomotive boiler bursting with only 75 cubic ft. of steam, of a pressure of 140 lbs. per square inch, there would be a considerable expansive action after the plates were rent open. But this amount of steam, if expanded 685 cubic ft., equal to the volume of a sphere 11 ft. in diameter, before its pressure was reduced to that of the atmosphere, could hardly produce any very violent effects. So much of it would escape on the first opening of a seam of rivets, or other outlet, that a great part of the steam would be gone before the parts of the boiler could be completely separated. The range of action of this amount of steam would also be comparatively short, as it would have to expand only about ninefold before all its expansive power would be gone. It is altogether improbable that, if steam only, of 140 lbs. to the square inch, were let into a close vessel calculated to burst at that pressure, the explosion would have the violence of a boiler explosion under the usual circumstances. The laws of expansion of compressed air are nearly the same as those of steam, and vessels employed in pneumatic apparatus are occasionally exploded, with an audible report and a smart shock, it is true, but without that terrible energy in which steam boiler explosions so much resemble the explosion of gunpowder. Steam cylinders sometimes fail; generally, however, from the concussion of the piston against water collected in the cylinder; but in such cases, with steam of nearly the full boiler pressure, and although the cylinder is formed of brittle cast iron, the broken parts are not projected violently away. In order to project bullets by steam, Jacob Perkins employed pressures of from 300 lbs. to 950 lbs. per square inch, whilst one ounce of fine powder, to the detonation of which steam boiler explosions are so frequently compared,

will project a 24 lbs. ball 300 yards; 225 yards being the least range, in such a proof, at which the powder is received into the service. But whatever may be the force of steam acting by itself, the sudden liberation of the heat, stored up, under pressure, in a considerable quantity of water, as in a boiler explosion, would develop an additional force. If, upon investigation, this force appears to be sufficient to account for the violent explosion of steam boilers, after rupture has once commenced, in consequence of defective material or construction, and, as we may suppose, under an ordinary pressure, we shall not need to assume and to account for the existence of extraordinay pressures like those with which Mr. Perkins experimented. If we consider heat as the source of power, and that the action of heat upon matter is always attended by the production of power, we shall be enabled to form a tolerable idea of the force concealed in a large body of highly heated water. The mechanical theory of heat has now attained such general acceptance, that it is sufficient to bear in mind that the "unit of heat," or the total quantity of heat capable of raising the temperature of one English pound of water through one degree of the Fahrenheit scale—or, which is the same thing, that of 100 lbs. of water through .01 of a degree, or .01 lb. of water through 100 deg.—that this quantity of heat, independently of the medium through which it is exerted, possesses the same amount of power as would be required to raise 772 English pounds through a space of one English foot, or 1 lb. through 772 ft., or 772 foot-pounds. If the addition of one degree of temperature to one pound of water be an addition of such a force, the addition of 100 deg. to 10,000 lbs. of water is an addition of 1,000,000 times the same force. In actual practice, the combustion of a pound of coal imparts to the water in a steam boiler about 10,000 units of heat, equal to the evaporation of 8 lbs. or 9 lbs. of water of ordinary temperature; and as in ordinary working, and under many losses and disadvantages, a pound of coal exerts about one-fourth of one horse power for one hour, or 15 horse power for one minute, or 900 horse power for one second, the heat stored up in 10,000 lbs. of water, in raising it through 100 deg. of temperature, is practically and actually equal to 25 horse power exerted for one hour, or 1,500 horse power exerted for one minute, or 90,000 horse power exerted for one second! The heating of 10,000 lbs. of water through 100 deg. of temperature represents but a small part of the heat contained in an ordinary steam boiler; yet it practically requires the combustion of 100 lbs. of coal to effect it, and the heat imparted is equal to that expended in the conversion of about 870 lbs. of water, of ordinary temperature, into steam. In a boiler explosion the contained heat is all disengaged in perhaps one or two seconds.

Recurring to the locomotive boiler, with 75 cubic ft. of water space and 75 cubic ft. of steam space, the corresponding weight of water would be 4,650 lbs., whilst the steam, even at 140 lbs. pressure, would weigh only 26 lbs. The temperature of this steam, however, which is the temperature also of the water from which it is formed, is 361 deg., and the water is heated therefore 149 deg. above the temperature at which it would produce steam, in the open air, of atmospheric pressure. Water could only be heated to this temperature by being confined under a corresponding pressure, and if, when the water has been so heated, the pressure is removed, the water cannot remain in its original condition as water merely, but a part of it becomes immediately converted into steam. 4,650 lbs. of water, heated to 361 deg, contains as much heat, or as many "units of heat," over and above the heat at which it gives off steam of atmospheric pressure, as are contained in 577 lbs. of steam of a total temperature of 1,200 deg. It is fair to presume, therefore, that upon the sudden liberation of the pressure under which 4,650 lbs. of water had been heated to 361 deg., about 577 lbs. of it would be immediately converted into steam. This quantity is more than twenty-two times greater than that of the steam originally contained in 75 cubic ft. of space, and at a pressure of 140 lbs. per sq. in.

If we suppose a considerable rupture of any part of the boiler, anywhere above the water-line, the steam already formed, would rush out with a velocity at first of about 2,000 ft. per second, Before the heat, contained in the water. could so far overcome the inertia of the water as to disengage additional steam, the upper part, or steam space of the boiler, might be nearly emptied. The steam which would inevitably rise from the water would thus strike at a very great velocity upon the upper part of the boiler, and no doubt, as Mr. D. K. Clark has suggested, in a com-

munication to the "Mechanics' Magazine," of 10th February, 1860, the steam carries a great quantity of water with it. In some of the earlier locomotives, having a deficiency of steam room, the partial removal of the pressure from the water, by opening the regulator or "throttle," was attended by a rise of the water to the extent of from 8 to 10 in. But whilst this result attended the removal of perhaps $\frac{1}{10}$ of the superincumbent pressure, its sudden and entire removal would cause a tremendous blow to be discharged—whether by the steam alone or by the combined steam and water—upon the sides of the boiler, sufficient, no doubt, not only to extend the rupture already existing, but to completely rend the boiler in two or more parts. In the case of the explosion at Birmingham, on the 5th March, 1857, of engine No. 175, belonging to the Midland Railway Company, the boiler was broken into 17 pieces. These effects would follow when the boiler had ruptured, in consequence of some defect in its structure, under a moderate working pressure, as well as under such immense pressures as are commonly assumed in cases of violent explosion. There is reason to believe that steam alone, striking at a great velocity upon a solid surface, can discharge a violent blow, in addition to whatever effect it may produce by its pressure when at rest. Mr. D. K. Clark has mentioned to me that where he had applied an indicator to a locomotive cylinder in which there was little or no compression, the sudden admission of steam through a large steam-port not only carried the pencil of the indicator above the point corresponding with the highest pressure in the steam chest, but a positive blow was discharged upon the finger when placed upon the pencil holder of the indicator. The same gentleman has mentioned to me also a fact which has been observed in the working of the Cornish engines, where steam of moderately high pressure is admitted into large cylinders, sometimes 100 in. in diameter. The cylinder covers are found to "spring" with each admission of steam, indicating a smart shock in addition to the pressure, which, after the piston has commenced its stroke, can only act statically upon the cylinder cover. Some years ago, and before the days of steam gauges, one Signor Morosi maintained the extraordinary opinion that on the stoppage of the piston at each end of its stroke, the whole force of the steam was so violently stopped in its motion as to strike back forcibly into the boiler, like the water in the hydraulic ram, impinging as would a solid body upon the boiler plates.* The percussive action of steam is certainly not so great as this; for it is only when steam strikes through an intervening space upon an unyielding surface and with a velocity of several hundred feet per second, that it can be considered to act with any amount of percussion worth mentioning, and not when reacting (if indeed it did react) against a large body of steam within a boiler, and at the slow speed of a steam-engine piston, gradually extinguished as its motion is at each end of its stroke. And, of course, upon Signor Morosi's notion, the boiler should explode, if at all, when the engine makes its first stroke. In practice, the steam gauge, which has since come into general use, is found to indicate a constant pressure without reference to the changing of the strokes of the piston, excepting where the steam room of the boiler is very much too small.

But the momentum of the combined steam and water, discharged, as Mr. Clark has suggested in his communication already referred to†, would probably be sufficient to overcome the resistance of the material of the boiler and to rend it open, not only along seams of rivets, but, as is often the case, through solid iron of the strongest quality. The velocity with which the steam and water would strike would depend upon the extent to which the steam-space of the boiler had been emptied of steam, before the inertia of the boiler had been overcome by its contained heat. The water carried

* Dr. Alban on the "High-pressure Steam-engine," translated by Wm. Pole (p. 27). London: Weale, 1848.

† "The following is a copy of Mr. Clark's letter:

TO THE EDITORS OF THE "MECHANICS' MAGAZINE."

11 Adams street, Adelphi, London, Feb. 9, 1860.

GENTLEMEN,—I have within the last few months given some attention to the subject of boiler explosions—their causes, and their *rationale*. I observe, in the discussions that have appeared in contemporary papers, that the percussive force of the steam suddenly disengaged from the heated water in a boiler, acting against the material of the boiler, is adduced in explanation, and as the cause of the peculiar violence of the result of explosion.

Now, gentlemen, a little calculation would show that the percussive force of steam is not capable of causing such destructive results as are occasionally produced; and I beg leave to suggest that the sudden dispersion and projection of the water in the boiler against the bounding surfaces of the boiler is the great cause of the violence of the results: the dispersion being caused by the momentary generation of steam throughout the mass of the water, and its efforts to escape. It carries the water before it, and the combined momentum of the steam and the water carries them like shot through and amongst the bounding surfaces, and deforms or shatters them in a manner not to be accounted for by simple overpressure or by simple momentum of steam.

Your obedient servant,
D. K. CLARK.

with the steam would not retain its ordinary condition as a liquid, but, being completely pervaded by nascent steam, would have the character of an expansive body of more or less elasticity. The destructive effects produced by the inevitable concussion of such a body upon the upper portion of a cylindrical boiler (and the water being originally in the bottom of the boiler would only strike upwards) cannot be estimated therefore by multiplying its weight, as if it were a solid body, into the velocity assumed to be acquired in the distance through which it would be projected against the iron shell of the boiler. It is very likely that the momentum of the steam and water is expended mainly in breaking the plates, especially through strong solid iron, and that if no additional force were afterwards brought into play the ruptured parts of the boiler would drop to the ground, or, at the most, be projected only to a short distance. But at the moment when the steam and water rise to the upper part of the boiler, and, indeed, until a large outlet is provided (as when, perhaps, the boiler is forced completely open), the quantity of steam disengaged will be very small indeed; not greater than the quantity originally contained in the steam-space of the boiler. Whatever may be the quantity of heat in the water, it cannot convert any portion of the water into steam of a greater pressure than that under which only the water was originally heated; that is to say, water heated, for instance, to 361 deg. cannot at that heat produce steam, spontaneously, of a greater pressure than 140 lbs. per sq. in. It is after the boiler has been rent completely open, and after its separated portions have, perhaps, been started upon different courses through the air, that the great disengagement of steam from the heated water must take place. This phenomenon can only occur after the boiler has been rent completely open, or, at least, when the water is no longer confined within its original limits, because the original capacity of the boiler would be insufficient for the disengagement of the steam, which, as it can never rise much above its original density, can only disengage itself upon the expansion of the water in which it was previously confined. Assuming 577 lbs., or 9.25 cubic ft., of the water contained in the locomotive boiler, already described, to be converted into steam of atmospheric pressure, it would form 15,188 cubic ft. of steam, equal to the volume of a sphere of 31 ft. diameter; and until the disengaged steam had expanded to this volume at least, the parts of the exploded boiler would be within the range of explosive action. Under the velocity with which, as in the explosion of large boilers, more than one ton of elastic vapor would discharge itself into the air, the projection of fragments of the boiler, weighing 5 cwt., to a distance of 350 yards, as in the explosion at Wharton Colliery, near Chesterfield, in June, 1856, is not perhaps anything to be wondered at.

Under the foregoing explanation of boiler explosions their results are produced by a series of consecutive operations, the first of which is the rupture of some portion, generally a defective portion, of the shell of the boiler; the rupture, unless it be of considerable extent, occurring generally—in cases of violent explosion—above the water line. If a narrow rent take place in the bottom of the boiler the pressure upon the water will not be removed until the water falls to the level of the discharging opening; and hence, as the water is not likely to escape with very great rapidity, no percussive action will occur within the boiler, from steam, either disengaged by itself, or in combination with water; and the steam which is disengaged from the escaping water will be already out of the boiler at the moment of its disengagement.

The distinct and consecutive operations into which a boiler explosion, although practically instantaneous, may probably be resolved, are, therefore these:—

1. The rupture, under hardly if any more than the ordinary working pressure of a defective portion of the shell of the boiler; a portion not much, if at all, below the water line.

2. The escape of the free steam from the steam-chamber, and the consequent removal of a considerable part of the pressure upon the water, before its contained heat can overcome its inertia and permit the disengagement of additional steam.

3. The projection of steam, combined as it necessarily must be with the water, with great velocity and through a greater or less space, upon the upper sides of the shell of the boiler, which is thus forced completely open, and perhaps broken in pieces.

4. The subsequent disengagement of a large quantity of steam from the heated water now no longer confined within the boiler, and the consequent projection of the

already separated parts of the boiler to a greater or less distance.

The rapidity of the escape of the steam, through a narrow opening, may be understood practically by observing an indicator diagram, taken from a locomotive cylinder when the engine is running at a high speed. The driving-wheels, at high velocities, revolve between four and five times every second, and each cylinder must exhaust twice at each revolution, or perhaps ten times in 1 sec. An examination of the indicator diagram will show, moreover, that the actual exhaustion, at each half-revolution of the wheels, does not occupy much, if any, above one-fourth of the time in which such half-revolution is made —each complete exhaustion of a cylinder-full of high-pressure steam occupying, therefore, but about one-fortieth of 1 sec., notwithstanding the length and tortuous character of the exhaust passages, and the comparatively gradual opening of the valve.

The force with which steam in motion will take up and carry water with it may be seen in the "Automatic Injector," or feed water apparatus, of M. Henri Giffard, as made by M. Flaud, of the Rue Jean Goujon, Paris, and more recently, by Messrs. Sharp, Stewart & Co., of Manchester, and the Rogers Locomotive and Machine Company, of Paterson, U. S. In this apparatus, a jet of steam discharged through a conical nozzle, draws up a considerable body of feed-water and impels it, first for a short distance through the open air, and thence, through a valve, into the same boiler from which the steam was originally taken. The under side of the clack valve—or so much of its under side as receives the impact of the water before the valve is raised from its seat—has, of course, less area than the upper side, on which the pressure within the boiler is exerted. Hence, to force water into the boiler against a pressure of, perhaps, 120 lbs. per sq. in., a pressure of, probably, at least 175 lbs. per sq. in. of the under side of the valve, has to be first exerted by the jet of combined steam and water. The jet at the same time is very small, and must move with considerable friction, which, therefore, by so much diminishes its original force of motion.

Where, therefore, a rupture is not attended by explosion it is to be presumed either that the relief of pressure is not so sudden as to induce percussive action by the steam spontaneously generated, or else that, even with the partial or total removal of the pressure, the quantity of heat stored up in the water is insufficient to complete the explosion. If a very small crack occur above the water line, or if a considerable aperture be very gradually opened, the removal of the pressure upon the heated water will be so gradual that no violent percussive action may be induced, and, as has been already observed, if the rupture occur below the water line, the pressure upon the water may not be removed until it has been almost wholly discharged from the boiler. The dome covers of locomotive boilers are sometimes blown off without explosion, but here it is probable that the fastening bolts do not all give way at once, and that the opening for escape enlarges gradually before the cover is forced completely off. In 1853, the boiler of locomotive No. 4 of the New York and New Haven Railroad, ruptured along the junction of the barrel of the boiler with the dome. The steam was lost and the train detained, but no further damage was done. In the winter of 1856–7 the boiler of one of the locomotives of the New York and Harlem Railroad ruptured through the underside of the cylindrical barrel, the results being similar to those just mentioned.

Another case, which came under my own observation, was that of a locomotive fire-box, which was ruptured at the Dunkirk shops of the New York and Erie Railroad. One seam of rivets had opened, on the outside fire-box, 1 in. in width, and perhaps 2 ft. in height. The further opening of the seam had been prevented by the framing of the engine, which extended along the side of the fire-box. No violent consequences attended this rupture. In his last report, H. W. Harman, C. E., Chief Inspector to the Manchester Boiler Association, states that in one case which occurred under his inspection, an oval flue collapsed with complete rupture of the plates, in consequence of the gradual admission of steam through the stop-valve of an adjoining boiler, and of higher pressure than the flue was capable of sustaining. "But," adds Mr. Harman, "no explosion occurred; it came quietly down, and the contents were discharged into the boiler house without any report whatever; and in another case arising from deficiency of water, the plates became overheated and flattened sufficiently to derange the seams, and a portion of the water escaped, also without concussion."

As already observed, the percussive action exerted by the combined steam and water, upon the sudden removal of the pressure, must be exerted mainly upwards, and probably the larger number of exploded boilers first give way in the upper part of the barrel. Comparatively few locomotive boilers ever leave the rails when they explode, unless the roof of the inside fire-box is crushed down. In February, 1849, the boiler of a locomotive employed on the Boston and Providence Railroad, United States, exploded with great violence whilst the engine was running with its train, and just after the steam had been shut off in approaching the Canton station. The engine did not leave the rails, but ran some distance after the explosion. The explosion of engine No. 58, upon the New York and Erie Railroad, in the summer of 1853, was attended with much the same results. The engine Wauregan, the explosion of which has been already mentioned, was not moved from the rails. Locomotive No. 77, of the New York Central Railroad, exploded in the winter of 1856-7, whilst running with a train, and just after the steam had been shut off. The engine did not leave the rails. Much of the iron in the barrel of the boiler was nearly as brittle as cast iron. Engine No. 23, of the Baltimore and Ohio Railroad, exploded violently at about the same time and in nearly the same manner. The engine of which the boiler burst in Messrs. Sharp, Stewart & Co.'s Works, in the summer of 1858, was not thrown from the rails, although the explosion was one of terrific violence. Nearly all of these explosions occurred in the waist of the boiler, towards the smoke-box end. In but one of the six explosions just mentioned was there any evidence of the overheating of any portion of the boiler. The tubes were in nearly every case bulged outwards beyond the original diameter of the boiler, showing that in the disengagement of steam from the water contained among them a considerable outward pressure had been exerted; although the closeness of the tubes, and the consequent want of any clear space through which the disengaged steam could strike, precluded the supposition of percussive action, which, indeed, had it occurred, would have broken the tubes to pieces, and driven them in every direction, instead of bending them merely.

In the case of the locomotive Irk, which exploded in the Machester engine-shed of the Lancashire and Yorkshire Railway, in February, 1845; in that of the explosion at Rogers, Ketchum & Grosvenor's, in May, 1 51; in that of engine No. 100, which exploded on the New York and Erie Railroad, in 1852 I believe, and in the case of the explosion of an agricultural engine, at Lewes, Sussex, in September last, the roof of the fire-box was in each case forced downwards, the steam discharging below, and the engine was, in every instance, thrown into the air. Considering that the ordinary pressure upon the crown-plate of a locomotive fire-box is from 80 to 150 tons, there is no difficulty in accounting for these results, after the plate has once gone down.

The boiler explosion which occurred at Messrs. Warburton & Holker's Works near Bury, on the 15th of August, 1856, was believed to have commenced in the bottom of the boiler. An extensive crack was known to have existed there, and it had been twice patched, notwithstanding which, a considerable breadth of iron was afterwards found to have been reduced to a thickness of only $\frac{1}{16}$in. But as the boiler was 36 ft. 6 in. long, and no less than 9 ft. 1 in. (109 in.) in diameter, and as it was worked, after its $\frac{7}{8}$th in. plates had been 11 years in use, at a pressure of 40 lbs. per sq. in., the final rupture of the bottom was in all probability instantaneous for a great length, especially as the boiler was riveted up with continuous seams, or seams which did not break joints with each other! This huge bomb-shell was said to have contained 56 tons of water at the moment of explosion; which quantity heated to 287 deg., corresponding to the pressure at which the explosion took place, would have given off at-least $3\frac{1}{2}$ tons of steam! It has, indeed, been assumed, that in many cases of explosion, all the water previously contained in the boiler is converted into steam. Mr. Edward Woods once mentioned, at the Institution of Civil Engineers, an instance which came under his observation, in 1855 I believe, and where, after a locomotive boiler had burst, the whole of the water was found to have completely disappeared. Mr. Vaughan Pendred, of Dublin, has informed me that he observed a similar result after he had exploded a small boiler, well supplied with water, for the purpose of experiment. He had erected a fence of boards about the place where the boiler was allowed to burst, but on going to the spot immediately afterwards no traces of water could be seen.

I cannot adopt the idea, however, that all the water, heated, probably, to less than 400 deg., is actually converted into steam. It is, no doubt, dispersed in a state of minute division and to a great distance; but the greater portion of it must still maintain its existence as water, since its contained heat is insufficient to convert it into steam. But there can be no doubt of the sudden generation of steam and projection of the water, when the pressure, under which water has been heated, is suddenly removed, and it is probable that water, heated in the open air to 212 deg., would be sufficient to produce violent explosion if suddenly placed in a vacuous space, corresponding, in its proportions to the contained water, to an ordinary boiler. A boiler, 24 ft. long and 10 ft. in diameter, burst with great violence on the 9th December, 1856, at Messrs. Cresswell & Son's ironworks, at Tipton. In this case it was observed that the floor of the boiler-house, immediately after the explosion, was covered with water, and this fact was taken as evidence of a sufficiency of water in the boiler. The boiler had been in use for some 18 years, but its plates had retained an average thickness of $\frac{3}{8}$ in. Had the plates been of good quality originally, and had they suffered no deterioration in the long time during which the boiler had been worked, the bursting pressure would have been 167 lbs. per sq. in. The explosion of the boiler was attributed to overpressure, although the regular working pressure was but 17 lbs. per sq. in.

The idea has been already suggested that heated water, if suddenly placed in a vacuous space, would disengage steam with great violence. The result would be necessarily the same whether the pressure, under which the water had been heated, were suddenly removed by exhaustion or by condensation. And if it were purposely sought to condense the steam in the upper part of a boiler, this could be effected with lightning-like rapidity. When steam of considerable pressure is discharged into a condenser of suitable capacity, the condensation is so instantaneous that the index of the vacuum gauge does not move at all. Even in surface condensers, in which the steam is let in upon several hundred square feet of tubular surfaces, kept cool by a constant circulation of water, the same instantaneous action takes place. If, therefore, a sufficient quantity of cold water—or water considerably below the boiling point corresponding to the pressure—were suddenly thrown up among the steam, its condensation would as suddenly take place. An instant can thus be conceived in which no pressure would exist upon the water, which, as soon as its inertia could be overcome by its contained heat, would, therefore, be thrown violently against the upper part of the boiler, causing its explosion in the manner already explained. Whether, in the practical working of a steam boiler, circumstances ever arise in which such condensation could occur, is a matter of conjecture. In locomotive engines, for example, the feed water is commonly pumped into the boiler at two points on either side, a little below the ordinary water level. With both pumps on, from 100 to 175 cubic inches of water are pumped in at each revolution of the driving wheels; and at a speed of even 30 miles an hour, from 10 to 15 cubic feet, or from 600 lbs. to 1,000 lbs. of water would be pumped in every minute. If this water were pumped in at the water level, it might not, obstructed as its descent would be by the closely packed tubes, mix with the water already in the boiler, until after some minutes; especially if the engine were running by momentum only, after the steam had been shut off, and when, therefore, but very little steam would be in process of generation, and when the circulation of the water would be consequently sluggish. If a stratum of cool water were to accumulate over the tubes, it would require a long time to heat it, especially if the draught had been stopped by shutting off the steam. Indeed 10 cubic feet of feed water, without circulation and consequent mixture with the hot water already in the boiler, would not, even when in contact with the heating surfaces, become heated to the boiling point in much less than a quarter of an hour. As long, however, as this water remained quiescent, the steam accumulated over it would be condensed only very slowly. But if, as by suddenly turning the steam again into the cylinders, the diminution of pressure, and consequent rise of water, were such as to throw up a considerable quantity of it into the steam chamber, the free steam might be instantly condensed, and, in such case, the reasoning already adopted would support the probability of instant explosion. In this case, the actual occurrence of which is not, perhaps, impossible, it would not be necessary to assume the existence of any defect in the boiler; for, when the water

once struck violently, the soundest iron would probably be broken, and the strongest workmanship destroyed.

Locomotive boilers often burst in the plates next to the smoke-box, beyond the reach of the fire, and where the boiler is believed to be stronger than about the fire-box. As has been observed, the dome, if it open from the ring of plates in question, weakens it materially; but explosions have occasionally occurred in this part of a boiler, either having no dome, or having one only over the fire-box. A fact which was some time since communicated to me by George S. Griggs, Esq., Locomotive Superintendent of the Boston and Providence Railroad, U. S., may assist in explaining this somewhat anomalous mode of explosion. In one or two cases of locomotive boiler explosions, Mr. Griggs found, upon examination, that whilst none of the upper tubes had been burnt, others, lower down, exhibited unmistakable indications of having been smartly scorched; the solder used in brazing being more or less melted. The tubes being closely packed in the boiler, it appeared that the heat passing through them had dispersed the water from their sides; the water-level being but about 15 in. above, and the consequent pressure of water, resulting from this amount of "head," being only about one half pound per square inch to overcome the violent disengagement of steam in the restricted passages below. The admission of water through the "check-valve" of the pump would suddenly cool the parts of the boiler with which it came first in contact, and would, no doubt, cause the partial return of the water to the surfaces from which it had been expelled. Sufficient steam might be thus disengaged, by 2 cwt. or 3 cwt. of highly heated copper or brass tubes, to exert a sudden and powerful strain upon the surrounding parts. Mr. C. Wye Williams has mentioned, in his work on the Combustion of Coal, a circumstance similar to that observed by Mr. Griggs. In one of the deep and narrow water-spaces of the boilers of the Great Liverpool steamship, the engineer found, on the first trip of that vessel to New York, in 1842, that the side plates were constantly giving way. On tapping a gauge-cock into the space, several feet below the water level, only steam was discharged, although the water was, at the same time, standing several feet above. In nearly all American and in the majority of French locomotives, of recent construction, the tubes are disposed in vertical rows, in order to assist the circulation of the water. Mr. Griggs has assured me that some of his engines, with closely packed tubes, have actually made steam more freely after he had plugged the ends of ten or a dozen tubes, one over the other, in the middle of the boiler. As long as the water was not in complete contact with these tubes, the heat which before passed through them was to a greater or less extent lost. I have myself observed that a class of locomotives having 130 tubes, 2 in. in diameter, made steam more freely than another class, in all respects the same, with the exception of having 144 tubes, $1\frac{3}{4}$ in. in diameter, although the actual extent of heating surface was hardly more in the former than in the latter case.

The quantity of water contained in steam boilers of a given length, and the consequent quantity of explosive matter which they contain under any given pressure, is, practically, as the square of their diameters; and although different boilers, of the same materials and workmanship, are believed to be equally strong to resist rupture when the thickness of their plates bears the same ratio in every case to their diameter, the real danger, which ensues after rupture has actually commenced, may be estimated, so to speak, as the square of their diameter and directly as their length, or, in other words, as directly proportional to the quantity of water which they contain at any given temperature. Although locomotive boilers, perhaps, sustain a greater proportionate strain than ordinary land boilers, and are, for that reason, somewhat more liable to explosion, the effects resulting from their explosion are seldom anything like those which attend the destruction of large land boilers, even when worked at very moderate pressures. The Great Eastern casing, which exploded with great violence on the trial trip last September, was no more than a large boiler, 7 ft. in diameter, with an internal flue of 6 ft. diameter, and which was, practically, unstayed. The collapse of this flue, under a moderate pressure, and the consequent liberation of the heat contained in the hot feed-water, of which the casing was made to hold 11 tons, was sufficient, upon the explanation herein advanced, to account for the disastrous character of the explosion.

I think there can be no doubt that a consideration of the expansive power of a large body of highly heated water, acting under the instigation of a sudden removal of the pressure (with the aid of which only it was possible to heat it above 212 deg.), is capable of clearing up much of the mystery which has for so long a time enshrouded the subject of Boiler Explosions. Such a consideration leads to a comprehensible and rational explanation of these disasters; one which, upon a rigid process of reasoning, appears sufficient to account for all or nearly all cases of the kind. Whilst the present essay may serve to commend this explanation to engineers and to the public generally, I hope it may also hasten the adoption of smaller and more numerous water spaces in steam boilers, as in the water-tube arrangement, which, with pure water, is, in my opinion, the safest, most efficient, and most economical yet devised for the generation of steam. But, above all else, public safety requires the frequent and systematic examination of all steam boilers, so that, as under the system of inspection which is in operation with such excellent results at Manchester and Huddersfield, defects may be discovered and remedied, in most cases before actual danger has been incurred.

All our knowledge of boiler explosions goes to show that, however possible it may be to accumulate an excessive pressure within a boiler, the actual explosion results, in the majority of cases, from some defect, either original or produced, and either visible or concealed, in the materials, workmanship, or construction of the boiler. Probably not much more than one per cent. of all the steam boilers made ever explode at all, and the results of systematic inspection show that a far higher percentage of the whole number of boilers are constantly in a condition inviting explosion, and from causes which a general examination would not only disclose, but of which it would also insure the removal.

ON SOME EVIDENCES AS TO THE VERY EARLY USES OF IRON.

By ST. JOHN VINCENT DAY, C.E., F.R.S.E.

From "Iron."

The literary research of Mr. Day has brought together much matter in relation to the extensive use of iron by man at a considerably more remote period than that which has been generally accepted. We give below the subject matter of two papers which he has read before the Philosophical Society, Glasgow. The note we published a few weeks ago on the "Iron Works of the Pharaohs," appears to afford strong confirmatory evidence of the correctness of many of his views.

That iron was amongst the very earliest of all the metals with which man was acquainted, we have abundant literary evidence. We are now in a position to show by two kinds of proof that iron was well known to man during the very remotest ages which can be reached with any degree of certainty—viz., that of the hieroglyphs and certain material specimens. These two evidences appear to establish the solid truth of that literary testimony which, in these latter days, has come to be doubted.

When examining works on the history of iron I have noticed the scantiness of the attempts to indicate what is absolutely ascertained, as distinct from traditions, concerning the use of this metal in pre-historic ages. I am disposed to believe this defect is merely a result of the trust placed in the teachings of a certain modern school, which, going dead against all literary testimony, declares for, and only for, the extremely high antiquity of copper and its alloys. When, too, certain researches into the "antiquity to man" claim that the appearance of iron marks a decided step on the road to a higher civilization, it is strange that their inquiries into the remotest limits of time, when man became an iron-using animal, bear no stamp upon them of having ever been directed to the earliest ages of those countries where contemporary testimony might be appealed to.

Belzoni has pointed out, that before the Persian invasion of Egypt by Cambyses, there was enough iron in the country to make instruments of agriculture with. Under the feet of one of the sphinxes at Karnak he found an iron sickle, now in the British Museum. The statue could not have been placed there subsequent to the age of the Ptolemies, for it appears that

since Cambyses destroyed the gods of Egypt, the country has never been invaded, so as to compel the people to conceal their idols. Sickles of the same form are to be seen in many agricultural representations in the tombs. This is a sufficient proof that at about B.C. 600 the blacksmith's art was practised in Upper Egypt. The evidence to be hereafter dealt with will, I believe, show that to Egypt, and not to Greece, must our attention be addressed for the solution of the problems relating to ancient metallurgy.

The paucity of researches on the knowledge and use of iron in pre-historic ages is the outcome of that dogma propounded by the Danish and Swedish antiquaries—Nillson, Steenstrup, Forchammer, Worsäee, and others—which teaches that men began with tools of stone, next used bronze implements, and lastly iron.

As to the beginnings of man, to do his work with stones, it is no business of ours just now to enter upon; but, concerning the further question, as to whether bronze and iron came to be *universally* employed in the order assigned to them by "progressive developists" amongst each of the sections of mankind now grouped into the Aryan, Semitic, and Furanian families, we have sufficient grounds to doubt.

It is asserted that the appearance of iron on the scene is an index that a higher civilization prevailed than when bronze is present. Sir Charles Lyell, quoting Morlot, says:—"The next stage of improvement that is manifested by the substitution of iron for bronze indicates another stride in the progress of the art. Iron never presents itself except in meteorites in the native state, so that to recognize its ores, and then to separate the metal from the matrix, demands no small exercise of the power of observation and invention." To the metallurgist, however, the picture at once presents a different view, and the bronze and iron order of succession does not receive the assent of our leading living metallurgist, Dr. Percy.

The higher antiquity of bronze is relied on, because no specimens of iron as old by, perhaps, thousands of years, have been found. But it is scarcely possible that a specimen of metallic iron should be found belonging to nearly so early an age as that to which even tolerably late bronzes belong. Iron, when exposed to the action of air or moisture, in a very few years becomes converted into an oxide so entirely that it is often not possible to recognize that it has ever been metallic.

The proto-Egyptian remains in Lower Egypt are generally accepted as the oldest relics of the human race. Confronting these structures with the bronze and iron succession dogma, as educed more especially from Scandinavian philosophy—How does the dogma fit the facts before us? The supports reply, "Exactly," for bronze was compounded of such proportions of the two metals that the resulting alloy would cut stone as well as the steel chisels of to-day. This is rather a begging of the question, and specially illogical. Since bronze is slowly oxidizable, if it was really used in Lower Egypt, we should find specimens in or about the monuments. Yet, so far as I have been able to ascertain, not a single relic has been found throughout the whole Nile Valley which can be pronounced as old as the material and hieroglyphic testimony we possess regarding iron.

Not only are iron instruments depicted in the tomb pictures of the fourth dynasty at Memphis, but at Memphis itself among the monuments metallic iron has been found; and that in what is by universal accord the oldest building in the world. And in that particular building placed in such a way as could only have been done when the structure was in course of erection.

It may perhaps appear startling, but it is the fact, that though a lump of malleable iron was removed by blasting it out from the solid masonry of the great pyramid at Gizeh by Colonel Howard Vyse, 35 years ago, I have altogether failed to meet with any allusion to it by any writer in the history of metallurgy.

Mr. Hill discovered a piece of iron in an inner joint near the mouth of the southern air channel. It was extracted after removing by blasting the two outer tiers of the stones of the present surface of the pyramid. This specimen, with accompanying certificates, is in the British Museum. Its original thickness was probably $\frac{1}{4}$th in. In some parts it is now $\frac{7}{8}$, including the scale of rust, and in other parts it thins off to nothing. It has evidently been flexible, tough, wrought iron.

It is frequently asserted that the use of iron indicates a greater acquaintance with metallurgy than that of bronze. This is an erroneous conclusion, and one to which no

practical metallurgist would assent. It is scarcely possible to point out a simpler and more readily occurring result than the reduction of iron ores, than the process employed prior to the modern invention of cast iron. We must remember that there is no evidence that cast iron was known to the ancients, although certain writers have described the reduction of iron ore as being performed by mixing the oxide of the metal with carbonaceous matter, and subjecting the mixture to a heat of sufficient intensity to fuse it.

Now, it is the result of a very long experience that iron may be reduced without fusion; indeed, in the most perfect blast furnace operations, the iron is reduced by carbonic oxide before the charge reaches that portion of the furnace where fusion takes place (the smelting zone of Scheerer). When fusion does take place, we get from the furnace either cast iron or crude steel, the iron being combined with a portion of the carbon of the charge.

From what we know of the most ancient methods of reduction, the fusion of the metal by them was impossible. I believe it was obtained simply by heating the oxides in contact with carbon for a sufficient time to allow the carbon to attack the oxygen in the innermost parts of the lump of ore, by a process analogous to that of cementation; the result being a mass of malleable iron, which at a welding heat was hammered into a solid block. Hence the attempts in modern times to extol the difficulty of iron-making by supposing its fusion to have been necessary are very misleading.

Still farther light has been thrown on this subject by the observation of my learned friend the Scottish Astronomer Royal, that the iron of the limestone in Lower Egypt becomes washed out of the matrix, filters through, and accumulates in hollow spaces and fissures, just as it does in South Africa, on the eastern frontier of Cape Colony. But in the latter place the Kaffirs have been famous from time immemorial for taking some of the flaky ironstone thus formed, and, after heating it in little charcoal fires, beating it out into good malleable iron heads for their "assegais."

I do not, of course, presume to assert that this is by any means a proof that the proto-Egyptians did likewise, but put it forward as a more probable theory than that sometimes advocated, viz., that they used meteoric iron for their tools.

These native ironworkers do not act in accordance with the modernly assumed law of the universal succession of the stone, bronze, and iron ages, for these savages, who have never worked copper or bronze, are, nevertheless, most excellent workers in iron.

By another very ancient nation, the Chaldeans, we have substantial proof that iron was used. The relics of the iron manufacture are doubtless only those comparatively few specimens which have owed their preservation to the peculiar dryness of the place in which they were deposited. ' After the decay of the proto-Chaldean kingdom, *i. e.*, about B. C. 1600 to B. C. 625, when the Assyrians flourished, we find them as workers and users of iron. Layard found at Calah a large quantity of iron, armor scales from 2 to 3 in. in length, rounded at one end and square at the other, iron helmets inlaid with copper, etc., corresponding precisely in shape with those depicted in the sculptures.

It may be remarked that these specimens show that the Assyrians had acquired very considerable proficiency in the execution of complicated ironwork, requiring, too, very excellent iron to submit to the various strains inherent to shaping it as armor. Amongst the articles of tribute enumerated in the statistical table of Karnak, iron is mentioned as brought to the Egyptians by the inhabitants of Assyria, Persia, etc. It was occasionally exported in the ore.

Frequently the Assyrians overlaid iron with bronze, either entirely or partially, by way of ornament. Amongst the other "finds" at Nimroud, Layard mentions many in iron. Iron instruments of various kinds; swords, daggers, shields, the heads of spears and arrows, which fell to pieces almost as soon as exposed to the air, so that only a few specimens were preserved. The bronze shields had iron handles. As the crowning point of discussions bearing on the ancient use of iron, he adds: "Amongst the iron instruments were the head of a pick, a double handled saw (3 ft. 6 in. long), several objects resembling the heads of sledge hammers, and a large blunt spear head, such as we find from the sculptures were used during sieges to force stones from the walls."

While we have not at present sufficient knowledge to link together the chain of testimony by which to prove the centre at which iron smelting took its rise, but find it

prominently referred to in most ancient literature, and in none more decidedly than the earliest parts of the Hebrew Scriptures, we shall probably not err in venturing to suggest that it was first practised in the Highlands of Central Asia, prior to the great breaking up of the human family once cradled there, and their march north, south, and west to inhabit the earth. It is not improbable that subsequently, perhaps from the non-existence of iron ore in some of the regions to which they travelled, that this, as well as others of the arts, fell into disuse among some sections of this divided people, until in their progress they met with the ore, and either from traditions of the past, or by being subjected to conditions requiring the use of metals, their attention was directed to it. At such times the practice of reducing the ores and working in the metals would be revived, perhaps rediscovered. These independent occasions thus corresponding to the alleged first discovery of iron smelting ascribed by different peoples to themselves, as we find it recorded in such of their traditions as have reached us.

WOODEN RAILROADS.

By H. HAUPT, C. E.

Written for Van Nostrand's Magazine.

A former article on wooden railroads, published in "Van Nostrand's Magazine," has elicited some adverse criticism, but no reason has been assigned why they will not accomplish all that has been claimed for them.

Several communications have been addressed to the writer, soliciting more detailed information, answers to which will be found in the article now presented.

To develop the resources of a country, facilities for transportation are indispensable. Iron ore could be mined and lumber manufactured only to a very limited extent if wagon transportation for any considerable distance over common roads were necessary to reach a market. Where the business is sufficiently extensive to warrant it, and the capital can be secured, railroads, either narrow or ordinary gauge, will afford the best facilities. But there are many localities in which ordinary railroads are impracticable, not from physical, but from financial difficulties in the way of their construction. With a limited capital and a sparse population, railroads cannot be built, even in localities highly favored in natural resources for operations of quarrying, mining, and heavy manufacturing. In such cases a substitute for the wagon road, less expensive than the railroad, becomes a desideratum.

This substitute has been proposed in a new style of wooden railroad, costing but little more to construct than an ordinary wagon road, yet affording transportation at less than one-fifth the cost by wagon, and less also than the ordinary cost by rail, where interest on capital invested is considered. This road differs essentially from the ordinary tram-road, which consisted of sawed rails, about 3 in. wide, laid on cross-ties, and used with narrow tread iron-wheeled cars. Such roads, although some improvement on the common wagon road with its mud holes and deep ruts, have given very unsatisfactory results. The differences extend to the track, cars, and motive power.

TRACK.

The track is formed of heavy logs, hewed on the upper side to the width of 8 in., and on the inside at right angles, sufficiently deep to form a straight edge for the flange. These logs are buried so that the top, or rail surface, is almost level with the road surface, resting on stout sills at the ends and middle, to which they are secured by wedged tree nails. The rails, therefore, are solidly bedded, and not liable to warp or twist. Twenty feet would be a convenient length on curves, but on straight lines longer pieces could be used, the ties being 10 ft. apart. The grading of a sufficient width on a side hill with gentle slopes, would cost about $200 per mile for a 3-ft. gauge; but of course the cost of graduation will vary greatly with the locality. Ravines and small watercourses would in general be crossed with rough trestles or timber cribs. Hewing the timber would cost about $200 per mile. In a wooded country, where timber can be obtained along the line of the road, where no large bridges are required, and no rock to be excavated, the

cost of such a wooden railroad should be covered by from $500 to $2,000 per mile, depending upon the amount of earth-work.

CARS.

The cars proposed for such wooden railroads are simple frames placed on wheels, without springs, and covered with a floor of plank. The wheels are of wood, built up of pieces cut from 2-in. planks in the form of secular sectors, about 8 in. at the wide end. Four thicknesses of plank will build a wheel with a tread of 8 in. corresponding with the face of the rail. A cast-iron hub is inserted in the centre, through which an iron axle passes, and a cast-iron flange is bolted on the inside. The timber should be of hard wood, well seasoned, the sectors laid so as to break joint and well bolted. Diameter of wheels about 30 in. Such cars, if used with horses, will cost about $40 to $50, or about one-third the price of a farm wagon. They will carry 3 tons, and can be made by any rough hand who can use carpenter's tools. If designed for use with locomotives in trains, draw bars and springs must be used, and the cost per car increased.

MOTIVE POWER.

Horse or mule power can be used; but if the tonnage is considerable, it will be preferable to adopt a light engine of 6 or 7 tons, with wide driving wheels, covered with vulcanized rubber tire. Such engines can be manufactured at the Baldwin Locomotive Works, for about $4,000. Passengers could be carried on the proposed roads with such engines, at a speed of 10 or 12 miles an hour, which would make a great improvement on the stage coach.

Such roads would rot out long before they would wear out, and the answer to the objection that they are not durable is simply that they will last just as long as the cross ties on an ordinary railroad, and it will cost less to renew them. Post-oak ties in the South last from ten to fourteen years. The cost of transportation by wagons, for a distance of 25 miles, without return load, is 50 cents per 100 lbs., or $10 per ton of 2,000 lbs.

Assuming the tractive power on such a wooden road, for the purposes of an approximation, to be double that of an ordinary railroad, or 20 lbs. per ton, the angle of friction would be 48 ft. to the mile. And a horse exerting a power of 150 lbs., at $2\frac{1}{2}$ miles per hour, or four horses 600 lbs., would haul on a grade of 144 ft. to the mile one-fourth of the gross load on a level, or $7\frac{1}{2}$ tons—giving 6 tons of net load. As a trip of 25 miles, returning empty, could be made in two days, assuming a team to be worth $5 a day, the cost of the round trip would be $10 or $1.66 per ton, as against $10 per ton by wagon transportation; and this too on grades of 150 ft. to the mile, nearly—tolls for use of road not being included in either case.

This illustration will show the great economy of such roads over wagon transportation, even when operated by horse power; but where the business will warrant it, the rubber-tired locomotive should be used. If, after a few years, a business should be developed sufficient to justify the expense, an iron railroad could be substituted; of which the original grading would form a part—the expenditure would not be lost. It is also to be observed that the rails of the proposed wooden railroad being even with the surface of the road bed, or nearly so, would permit the same road bed to be used for ordinary vehicles.

COST OF OPERATING

the wooden railway, as compared with an ordinary iron road. Assume length of road 25 miles. Interest 10 per cent. and one engine only, to be provided with a minimum equipment of cars in each case. For an ordinary railway, with 45 lb. rails.

25 miles, $18,000 per mile, $450 000; interest	$45000
Road repairs, 1 man, per mile, (labor)	7500
Locomotive engine, $12,000; interest and repairs 20 per cent	2400
One good passenger car, $4,500; interest and repairs 20 per cent	900
20 freight cars, $800, $16,000: interest and repairs 20 per cent	3200
Engineer and fireman, $4.50 per day, 300 days	1350
One conductor for both freight and passengers, mixed train	750
3 brakemen, $1 per day	1080
Agent at each end of line	1200
Fuel for engine, 2 cords per trip, 1 trip per day	1200
Renewals of ties, $120 per mile	4800
Wear of rails 20 years, annual wear, $150 per mile	3750
Supervision	1000
Depots and siding repairs, etc.	800
Stationery, insurance, loss, damage and incidentals	1000
	$75,850

This is a moderate estimate of the cost of operating an ordinary railroad, with a minimum equipment, for one year, includ-

ing repairs, renewals, and 10 per cent. on capital, and amounts to about $3,000 per mile. If one-third of this income should be derived from passengers, and two-thirds from freight, carried at 6 cents per passenger and 10 cents per ton per mile, the number of passengers carried the 25 miles would be 16,180 and the number of tons 20,200; this amount of business would pay 10 per cent. on capital invested. To cover expenses and pay nothing on capital, would require a business of 6,140 passengers and 7,360 tons—yielding a revenue of $27,650.

A wooden railway for the accommodation of an equal business would require the following estimate:

25 miles at average cost of $1,500 $37,500; 10 per cent	$3750
Renewal of track once in 6 years, $33 per mile per annum	1155
6 hands for track repairs	1800
Engine, $4,000; 20 per cent.	800
Engineer	900
Train hands	1800
40 freight cars, $100; 20 per cent	800
4 passenger coaches, $250; 20 per cent	200
Agents	1200
Fuel	800
Supervision, insurance, stationery, incidentals	1500
	$14,750

To pay running expenses and 10 per cent. on capital will require an income of only $15,000 per annum. To cover operating expenses, without interest on capital or equipment, about $10,000.

The amount of business that would pay operating expenses only, without dividends, on an ordinary iron road, would pay operating expenses and a dividend of 40 per cent. upon the wooden railway; and the business that would pay 10 per cent. upon the iron road would pay 142 per cent upon the wooden road. To pay 10 per cent. upon the wooden road would require a business at the prices stated of 3,300 passengers and 4,000 tons freight.

The capacity of a wooden railway with a single engine of 7 tons and grades of 150 ft. to the mile will be estimated. Allow adhesion of engine, 3,200 lbs.; traction on level, 20 lbs. per ton; load on level, 160 tons; on grade of 150 ft., 40 tons; requiring at 3 tons to a car, 14 cars, or 12 cars exclusive of weight of engine. The net load carried would be about 28 tons.

A day's trip each way for 300 days would give an annual capacity of 16,800 tons. If the trade should be all one way, only half this amount carried and no passengers, $2 per ton for 25 miles, or 10 cents per 100 lbs., would pay running expenses on such a road, and 12 per cent. dividends; while an iron road could not be operated at all with ordinary equipment, inasmuch as the income would not pay running expenses.

The cases are numerous where such roads would perfectly meet the wants of the public in developing the resources of sparsely settled localities, and serving as valuable feeders to trunk lines. The estimate for capacity has been made for a single engine of 6 to 7 tons. If the weight or number of engines be increased, the capacity would be increased proportionally. The ultimate capacity with increased equipment would far exceed the requirements of any locality where such roads would be employed.

The question is often asked: What is the limit of grade that can be employed on such wooden railroad? The answer is, grade affects only the load which a given power can transport, and is independent of the road itself, gravity being a retarding force due to inclination solely. At the same time it is true that the more perfect the construction of the road bed and the machinery, the more rapidly does grade reduce the tractive power. On a well-constructed railroad 8 lbs. per ton will move a train, and a grade of 20 ft. to the mile will more than double the required traction for a given load. And every additional 20 ft. would require additional power equal to the resistance of the train upon a level. On a wooden railroad, assuming traction as 20 lbs. per ton, it would require a grade of nearly 50 ft. per mile to double the power, or with a given power to reduce the load one-half. On a grade of 250 ft. to the mile a team of four horses could haul five tons.

The adhesion of locomotives on ordinary railroads does not exceed one-fifth of the weight in drivers, and is measured by the friction of iron upon iron, but the friction of wood on wood is 50 per cent., and that of rubber on wood is probably greater; consequently rubber-tired locomotives could ascend much higher inclinations than ordinary engines upon railroads, the limit of which is about 800 ft. to the mile without load, and whole weight on drivers. The surplus adhesion, however, can not be utilized without a proportionate increase of cylinder power, which involves also increased boiler capacity.

Such wooden railways, operated either by locomotive or animal power, may become very important agencies in promoting the settlement of localities not supplied with railroad facilities and in developing mineral and agricultural resources.

In the last number of "Van Nostrand's Magazine," July, there is a statement that more than 100 miles of wooden railroads are in operation in Canada, in the province of Quebec alone. That the gauge is 4 ft. 8½ in., the running time about 16 miles per hour; but that trains have been run at the rate of 35 miles per hour. The cars have four wheels; some of the engines weigh 30 tons.

These rails were of sawed timber laid on cross-ties; and if such roads run with cars and engines with iron wheels at speeds of 16 to 35 miles per hour, and engines of 30 tons have proved so serviceable that their use is extending, there can be no room to question the success of the system here proposed, of solid rails permanently bedded, wooden wheels, light engines with rubber tires, and moderate speeds.

CHARCOAL FILTRATION FOR WATER WORKS.

From "Engineering."

A great variety of substances, both natural and artificial, have been, and still continue to be, used for the filtration of water as well on a large as on a small scale. These, however, for the most part —especially those used on the large scale —possess the power of mechanical filtration only, and most of them require to be frequently cleansed or renewed. To effect the perfect filtration of water it is necessary that the filtering media should possess the power of depriving the water of its chemical as well as of its mechanical impurities, and if these two properties are combined in one substance, so very much the better for simplifying the operation of filtration. This double qualification being possessed, in an eminent degree, by animal charcoal, has led to the general adoption of that substance for filtering purposes on a small scale. On a large scale, however, beds of sand and gravel chiefly continue to be used, simply because, until now, no means have been devised by which the valuable properties of charcoal could be rendered available. Even on a small scale its use was, at one time, attended with considerable inconvenience, inasmuch as, being used in fragments placed in layers, after a time the particles of charcoal became coated with impurities, and the pores being clogged the purifying action ceased. This objection, of course, still holds good in systems in which the charcoal is used in this manner, and although it may be cleansed by washing and baking, it is questionable whether it can ever be perfectly renovated. To meet the objections and to obviate the disadvantages attending the loose charcoal system, Mr. Atkins, several years since, invented and introduced a method of forming the charcoal into porous blocks of any required size, the manufacture being carried on at his works at Chepstow. The process of manufacture is as follows: The purest animal charcoal is first reduced to a fine powder, and is then mixed with Norway tar and other combustible materials in a state of fine powder. The mass is then kneaded into a plastic condition with liquid pitch, and is afterwards moulded into blocks of any required size or shape. The moulded blocks are then exposed to great heat, by which means all the combustible ingredients are burnt out, leaving the pure carbon in a solid form. The block is, as a consequence, perfectly porous throughout, the pores being the cavities from whence the combustible material has been burnt out. Of course there is a limit to the purifying power of these carbon blocks, as well as to the fragments, but the period of service of the former before cleansing is required, greatly exceeds that of the latter, whilst all that is necessary is to wash the block in warm water, which will remove the organic impurity. If, however, the carbon is used for filtering water containing much salts of lime, a hard incrustation will form on the surface of the block, which is easily removed by scraping when dry, after which the block is ready for use again.

Hitherto, the application of the solid carbon system, although extensive, has been confined to the filtration on a small scale, that is for household purposes, or at most for public buildings or industrial pro-

cesses. The increasing difficulty of obtaining pure water direct from the water companies, however, has been under Mr. Atkins's consideration for some time past, and he has recently patented a system of filtration by the block carbon system which is applicable to water works. This arrangement consists of brick tanks of a size proportioned to the amount of filtration to be performed, and divided up into a series of chambers The water is admitted into the first or settling chamber, whence it flows horizontally through a bed of sand held between two walls composed of perforated or porous materials. After the water has percolated through the sand bed, which deprives it of its chief mechanical impurities, it has to pass through a series of walls formed of solid carbon plates 12 in. square, and about 2 in. thick, set in an iron framing in a similar manner to panes of glass in a window frame. The frames are placed about 18 in. apart, and the number of these walls, through which the water has to pass, is governed by the amount of purification it is intended the water shall undergo, as well as by the character of the water. Of course the greater the number of walls, the higher the degree of purity attained, although some waters require much less charcoal filtration than others. After passing through the last wall of charcoal plates the water is conducted from each tank into a a storage reservoir from whence it is taken for distribution. The filtering capacity of each square foot of carbon plate has been ascertained to be from 300 to 500 gallons per 24 hours, so that, the distribution being known, the filtering area can readily be adjusted to meet the requirements of the supply. When the action of the plates becomes sluggish the coating of organic matter can be readily removed by washing in the way we have already indicated, whilst if any incrustation from the salts of lime should occur, the deposit can be easily scraped off when the plates are dry, the tank being of course thrown out of work for the purpose. If a plate become damaged or unfit for use, it can be removed, and replaced in a very short time, as, in fact, can each entire frame if necessary. It will be seen that as soon as the surfaces of the solid carbon blocks become encrusted with organic or other matter, or in other words, when the charcoal ceases to fulfil its proper functions, the water ceases to pass through, and thus the inert condition of the filtering media is at once indicated. This is a very important feature, inasmuch as in the loose charcoal system, or in any system of purely mechanical filtration, after the atoms making up the mass have become enveloped in the suspended impurities, the water will continue to flow through the interstices between the particles, and in time may leave the filter in a worse condition than when it entered. This contingency, however, is clearly impossible with the block carbon system, which appears to be well adapted for filtering water on the large scale, to which purpose we anticipate shortly seeing it applied. We are informed that Mr. Atkins has sent in an estimate for applying his system to the works of one large water company, and is in communication with several others upon the subject.

ON THE MOLECULAR CHANGES PRODUCED IN IRON BY VARIATIONS OF TEMPERATURE.

By Professor R. H. THURSTON.

From "Iron Age."

(Continued from page 179.)

48. Mr. Peter Spence gave a description of his experiments upon bars of cast iron, ½ in. sq., placed on supports 9 in. apart, and broken by carefully applied and steady pressure

Six experiments were made at 60 deg., and six at 0 deg. Fahr. He sums up the evidence thus:

"The bars at zero broke with more regularity than at 60 deg., but instead of the results confirming the general impression as to cold rendering iron more brittle, they are calculated to substantiate an exactly opposite idea, namely, that reduction of temperature, *cæteris paribus*, increases the strength of cast iron." He found this increase to amount to 3½ per. cent. between 60 deg. and 0 deg.

49. Subsequently, Mr. Spence made a more extended series of experiments.

He obtained 50 bars of cast iron (of mixed Scotch brands), each 3 ft. long and ½ in. sq., cut them into lengths of 1 ft., and mixed them thoroughly. Seventy pieces were tested at zero, after 48 hours' exposure to a freezing mixture of salt and ice, and 70 were tested at 70 deg. Fahr.

The breaking weights of the pieces averaged 430.3 lbs., warm, and 442.8 lbs. at zero, the weight being placed midway between supports 9 in. apart.

Mr. Spence finally says*: "I have no hesitation in giving it as an ascertained law, that a specimen of cast iron, having at 70 deg. Fahr., a given power of resistance to transverse strain, will, on its temperature being reduced to 0 deg., have that power increased 3 per cent."

Mr. Spence notices a circumstance, which occurred in the course of his experiments, which may throw some light upon the molecular constitution of metals, and thus, indirectly, upon the subject discussed. A weight of 449 lbs. had been suspended from one of the bars tested, for the space of nearly 2 min.; the bar finally broke after a single 1 lb. weight had been, without the slightest jar, lifted off—so slowly, in fact, that its upward motion was barely perceptible. It may be imagined that the fact is new evidence of the existence of viscosity in even cold iron.

50. The most complete investigation ever made, particularly to determine the effect of changes of temperature in modifying the physical properties of iron and steel, was that of Knut Styffe, the director of the Royal Technological Institute, at Stockholm, Sweden, and supplemented by the experiments of Christer P. Sandberg, who translated the report of Styffe into English.

The work of the first named engineer was done at the instance of a committee appointed by the King of Sweden. It was commenced by Professor Angstrom, continued by Herr R. Thalen, of the University of Upsala, and by Engineer K. Cronstrand, and it was finally concluded, with the assistance of Cronstrand and Lindell, by Styffe, who wrote out the results of the whole investigation and made the report public.

These labors were begun in 1863 and extended over several years.

The conclusions of Styffe were:

"(1). That the absolute strength of iron and steel is not diminished by cold, but that, even at the lowest temperature which ever occurs in Sweden, it is at least as great as at ordinary temperature (about 60 deg. Fahr.)."

"(2.) That, at temperatures between 212 deg. and 392 deg. Fahr., the absolute strength of steel is nearly the same as at ordinary temperature, but, in soft iron, is always greater."

"(3.) That neither in steel nor in iron is the extensibility less in severe cold than at ordinary temperature, but that, from 266 deg. to 320 deg. Fahr., it is generally diminished, not to any great extent in steel, but considerably in iron."

"(4.) That the limit of elasticity, in both steel and iron, lies higher in severe cold; but that at about 284 deg. Fahr., it is lower, at least in iron, than at ordinary temperature."

"(5.) That the modulus of elasticity in both steel and iron is increased on reduction of temperature, and diminished on elevation of temperature; but that these variations never exceed 0.05 per cent. for a change of temperature of 1.8 deg. Fahr., and, therefore, that such variations, at least for ordinary purposes, are of no special importance."

51. An equally well conducted series of experiments on transverse strength and the flexure of iron and steel led to the following conclusions:

"(1.) Iron sustains, at lower temperature, a greater, and at higher, a smaller load than at the ordinary temperature, before it obtains any perceptible permanent deflections."

"(2.) The modulus of elasticity for steel and iron on flexure, may, for practical purposes, and without committing any considerable error, be generally assumed equal to that on traction. It is diminished by permanent deflection, but may be restored by heating, especially if raised to a red heat."

"(3.) By hardening steel its modulus of elasticity is diminished, but this diminution has not, in any of the hardened bars examined, amounted to more than about 3 per cent."

"(4.) The elastic force of iron and steel on flexion, as on traction, is increased on reduction of temperature and diminished on elevation of temperature. The amount of this increase or decrease for a change of

* London "Engineering," 1871; vol. 11, p. 173.

temperature equal to 1.8 deg. Fahr. (1 deg. centigrade) does not, however, in general, amount to more than 0.03 per cent., and, apparently, never rises to 0.05 per cent."

52. The experimenter states that "the results of the experiments given above are evidently opposed to the opinion hitherto commonly entertained, viz., that steel and iron become weak or brittle at low temperatures," and gives it as his opinion that the cause of the frequent breakage of rails in cold weather, and of articles made of iron and steel, is unequal expansion and contraction and the rigidity of supports, where, as is the case with rails, frost may very greatly affect them.

53. Sandberg, while admitting the care and the accuracy which distinguished this extensive series of experiments, still doubted whether the reasons just given were the sole reasons why metals should more readily break in cold than in hot weather, and, having obtained the consent of the State Railway Administration, he conducted a series of experiments, in the summer and winter of 1867, at Stockholm, to determine whether, with equal rigidity of supports, iron rails would yield with equal readiness to blows at the two extremes of temperature.

The rails experimented upon were each cut into two halves, and one piece was tested in cold, and the other in warm, weather, at temperatures of 10 deg. and 84 deg. Fahr., respectively. The supports at the ends of the rails were granite blocks, placed four feet apart, and resting on the smoothly levelled surface of the granite rock. They were broken by a heavy drop, weighing 9 cwt.

Sandberg's conclusions, from 20 experiments, are thus given:

"(1.) That, for such iron as is usually employed for rails in the three principal rail-making countries (Wales, France, and Belgium), the breaking strain, as tested by sudden blows or shocks, is considerably influenced by cold; such iron exhibiting, at 10 deg. Fahr., only from one-third to one-fourth of the strength which it possesses at 84 Fahr."

"(2.) That the ductility and flexibility of such iron is also much affected by cold; rails broken at 10 deg. Fahr. showing, on an average, a permanent deflection of less than one inch, whilst the other halves of the same rails, broken at 84 deg., Fahr., showed a set of more than four inches before fracture."

"(3.) That, at summer heat, the strength of Aberdare rails was 20 per cent. greater than that of the Creusot rails; but that in winter the latter were 30 per cent. stronger than the former."

Sandberg suggests that this considerable decrease of toughness at low temperatures may be due to the "cold shortness" produced by the presence of phosphorus.

Our knowledge on this point must remain imperfect until similar experiments have been made with iron free from phosphorus.

54. The researches above described constitute the experimental basis of our knowledge of the effect of change of temperature in producing alterations of molecular structure and of strength and resilience in metals.

A few other less elaborate, though instructive, experiments have been made, some of which enlarge our knowledge of molecular physics somewhat, although bearing less directly upon the problem under consideration.

55. Professor W. F. Johnson, in 1844, gave the results of experiments made under the direction of the United States Navy Department, which revealed the fact that the increased strength, at moderately high temperatures, which was noted by the committee of the Franklin Institute, was retained, on cooling, provided that the bars were submitted to powerful tension while heated.

Prof. Johnson reports* that "the average gain of length of bolts of iron treated at the Washington Navy Yard, by this same process, was 5.75 per cent., and the gain of strength 16.64, making, together, the gain of value 22.4 per cent.

"In many instances the experiments made at the Franklin Institute proved the gain of length to exceed 7 per cent. The report to the bureau also confirms what had been previously observed, viz., that the total elongation of a bar of iron, broken in its original cold state, is from two to three times as great as the same force would produce upon it if applied at a temperature of 573 deg., which force will, moreover, not break the bar at that temperature."

54. Professor Thompson has indicated† the existence of a resistance to molecular movement, such as has been referred to al-

* Senate Document, No. 1, 1844–5; and American Journal of Science and Arts, 1846, vol. 1, p. 300.

† Civil Engineers' Journal, Vol. 28.

ready, and designated "molecular friction." He calls it "viscosity." The term, thus used, designates a somewhat different property from that to which the name is generally applied, and which was illustrated by Tresca's experiments, already described, and other similar experiments.

He deduced the following:

(1.) That there is a certain internal resistance which is independent of the elastic properties of metals.

(2.) That it does not affect the coefficient of elasticity.

57. A singular action has been recently detected by W. H. Johnson*, which may prove instructive in this connection.

Iron was immersed in hydrochloric acid one or more hours, and then tested for elongation and breaking strain. The pieces were then heated and again tested, with the following results:

(1.) That immersion in acid diminishes the breaking strain of iron wire from ½ to 3 per cent., and of steel wire about 4.76 per cent.

(2.) That immersion in acid appears, in some cases, to diminish, and in others slightly to augment the elongation of iron wire, and to augment the elongation of steel wire about 30 per cent.

Heat restored to the iron its original toughness.

Pyroligneous and sulphuric acids had the same effect as hydrochloric, in different degrees.

Copper was not affected in this manner.

The cause of this peculiar action remains undetermined. The phenomenon is of interest principally as confirming an inference deducible from other experiments, viz., that, in general, circumstances tending to increase the strength of a metal, by molecular change, also tend to reduce its viscosity and its extensibility, and *vice versa*.

58. The experiments of Mr. Oliver Williams, in determining the change produced in the character of the fracture of iron by transverse strain, at extreme temperatures, were more evidently pertinent to this subject.

Mr. Williams says, of two specimens of nut iron, cut from different bars, made at Catasauqua, Pennsylvania: "These specimens were first necked with a cleft on one side only, and then broken under a hammer, at a temperature of about 20 deg. Fahr. At this temperature, both specimens broke off short, showing a clearly defined granular, or steely iron fracture. The pieces were then gradually heated to about 75 deg. Fahr, and then broken, as before, developing a fine clear fibrous grain. The two fractures were but 4 in. apart, and are entirely different."

59. It has been long known that a granular fracture may be produced by a shock, in iron which appears fibrous when gradually torn apart.

This was fully proven by Kirkaldy. Mr. Williams was, probably, the first to make the experiment just described, and thus to make a direct comparison of the characteristics of fracture in the same iron at different temperatures.

A fair inference from these experiments is, apparently, that a reduction of temperature increases the polarizing force, decreases the viscosity of the metal, and thus causes its fracture to assume the appearance which characterizes the fracture of substances which are remarkable for their rigidity; while elevation of temperature, increasing viscosity, allows greater extension before fracture, and this greater toughness is evidenced by the sort of fracture characteristic of less brittle materials.

60. Nothing in these experiments affords any indication of the effect of change of temperature, in this instance, upon the strength of the metal. It has, however, been shown that low temperatures increase the strength of metals, and Mr. Williams' experiments are confirmatory of the supposition, of which strong evidence has already been quoted, that it also decreases resilience, or the power of resisting blows and heavy shocks.

The experience of every mechanic who has observed the behavior of tools and of metals at different temperatures, also confirms this belief. Tools yield readily to blows, where exposed to severe cold, although not evidently weak under steady strain.

61. It has been remarked (Article 22), that we should anticipate that the effects of change of temperature would be most marked with metals of low melting points.

The observations of Prof. Fritzsche, who noticed that extreme cold produced upon tin an effect somewhat similar, but even more striking than that remarked by Mr.

* "Iron," April, 1873, p. 452.

Williams in the case of iron, may be accepted as corroborating this idea.

The well known variations in the ductility of zinc, when under varying conditions of temperature, are also noticeable evidence of the marked rapidity of such changes, where the range of temperature, within which the body remains solid, is narrow.

62. Reviewing the whole ground, it becomes evident that there still remains much interesting werk to be done in determining the precise effects of variation of temperature upon the strength aud ductility of the various metals, and particularly, in ascertaining the modifications of the general law, which may be due to differences in physical and chemical structure, where they are combined with the metalloids, or united as alloys.

Some of those effects which have been attributed to change of tenacity in the material may have been due, in some degree, to unequal expansion or contraction. It can hardly be doubted that such action often modifies, or even disguises, the change in character produced by real changes of intermolecular forces. It is certainly the fact that changes of molecular arrangement sometimes occur very slowly.

Ordnance of cast iron has been found to gain strength slowly, but probably steadily, for years after its removal from the foundry; the familiar belief that razors, out of use, recover the cutting quality lost by constant employment, may probably be founded on fact, and the writer has often noticed that cold chisels and similar tools, when found after long disuse and exposure to the weather, seem to have regained the strength and endurance of edge, the loss of which had probably caused the workman to throw them aside.

If this be the case, a sudden alteration of structure, such as may be produced by considerable changes of temperature may cause a change of quality, which only a long period of time may counteract. Such action would evidently be most marked with brittle, and least noticeable with ductile, metals, and the fact is further illustrated by the circumstance that *iron* castings, not infrequently, are broken while cooling after removal from the mould, while *bronze* castings are very rarely thus injured.

63. It seems, finally, very probable that additional investigation will be found to confirm our deductions from experiments already made, and will justify the following

CONCLUSIONS:

1. That the number and the nature of those molecular forces which determine the physical condition of matter are not yet fully ascertained, but that these forces manifest themselves in, at least, three distinct modes of action, and, as thus exhibited, they are known as repulsion, cohesion, and polarity.

2. That the force of repulsion is, apparently, heat-motion, or some closely related phase of energy; that the force of cohesion bears some resemblance to that of gravitation, but seems not to be identical with the latter, and that the force of molecular polarity, which determines the molecular relations of position, seems to bear some distant resemblance to that of magnetic polarity.

3. That the law which governs the variation in intensity of these forces with changes of intermolecular distances, is undetermined, and that it has not been expressed by any mathematical formula, except approximately and for a limited range.

4. That the magnitudes of the intermolecular spaces, and, consequently, the volume of any mass, are variable with changes in the relative magnitudes of the forces of cohesion and repulsion.

5. That the resistance offered to change of form is determined by the relations, in intensity, of the forces of polarity, and of those forces which determine intermolecular distances.

6. That, at the "absolute zero" (−461.2 deg. Fahr.), cohesion and polarity, and, consequently, the strength of the material, have their maximum value, heat energy having disappeared.

7. That at very high temperatures, heat energy exerts a separating force between particles, which entirely overcomes the other forces, and matter assuming the gaseous state requires the action of extraneous force to preserve its volume unchanged.

8. That, at intermediate points, matter in either the solid or the liquid state exhibits a definite degree of separation of molecules, which is determined by the intensity of the repulsion due to heat motion, a position of equilibrium being assumed which, with the same substance, is invariable for the same temperature. The application of some kind of force is required to disturb this equilibrium and to produce change of volume. The amount of this force is determined, for any given extent of disturbance,

by the maximum value of cohesion for the substance and the quantity of heat which has been required to raise it from the absolute zero of temperature. The sum of the applied force, and of the force consequent upon the presence of heat motion, must exceed cohesive force to produce dilatation, while this cohesive force, added to the externally applied force, must exceed the force of repulsion to produce diminution of volume.

9. That the distinction between the solid and liqid states of matter is due to the action, in the former, of the force of polarity, which gives stability of form, while in the latter this force is extremely feeble, and disappears altogether before the boundary line between the liquid and gaseous states is reached.

That combined stability and elasticity of volume may be produced by the equilibrium of attractive and repulsive forces, but that stability and elasticity of form demand the co-existence of cohesion and polarity.

10. That the general effect of increase or decrease of temperature is, in solid bodies, to decrease or increase their power of resistance to rupture, or to change of form, and their capability of sustaining "dead" loads.

11. That the general effect of change of temperature is to produce change of ductility, and, consequently, change of resilience and power of resisting shocks and of carrying "live" loads. This change is opposite in direction and, usually, greater in degree, than the variation simultaneously occurring in tenacity.

12. That marked exceptions to this general law have been noted, but that it seems invariably the fact that wherever an exception is observed in the effect upon tenacity, an exception also may be detected in the effect upon resilience. Those causes which produce increase of strength appear always to cause a simultaneous decrease of ductility, and *vice versa*.

13. That experiments upon copper, so far as they have been carried, indicate that, with that metal, the general law holds good.

14. That iron exhibits marked deviations from the law, between ordinary temperatures and a point somewhere between 500 and 600 deg. Fahr., the strength increasing between these limits to the extent of about 15 per cent., with good iron. That this variation becomes more marked and the observed effects are more irregular as the metal is more impure.

15. That above 600 deg., and, at temperatures below 70 deg Fahr., the general law holds good with iron, its tenacity increasing with diminishing temperature below the latter point, at the rate of from about 0.02 per cent. to 0.03 per cent., for each degree Fahrenheit, while its resilience decreases in a much higher but not well determined ratio for good iron, and to the extent of reduction to one-third its ordinary value or less, at 10 deg. Fahr., when "cold short," and, in the latter case, the set before fracture may be less than one-fourth that noted at a temperature of 84 deg. Fahr.

16. That the viscosity, ductility, and resilience of metals are determined by identical conditions, and that the fracture of iron at low temperatures has, accordingly, been found to be characteristic of a brittle material, while, at higher temperatures, it exhibits the appearance peculiar to ductile and somewhat viscous substances. The metal breaks, in the first case, with slight permanent set and a short, granular, fracture, and in the latter with, frequently, a considerable set and the form of fracture indicating great ductility. The variation in the behavior of iron, as it approaches the welding heat, illustrates the latter condition in the most complete manner.

17. That the precise action of the elements with which iron is liable to be contaminated, and the extent to which they modify its behavior under varying temperatures, remain to be fully investigated, but that the presence of phosphorus, and of other substances producing "cold shortness," exaggerates to a great degree the effects of low temperature in causing loss of toughness and resilience.

18. That the modifications of the general law with other metals than iron and copper, and in the case of alloys, have not been studied, and are entirely unknown.

19. That these conclusions are sustained by experiments of both physicists and engineers.

The practical result of the whole investigation is that iron and copper, and probably other metals, do not lose their power of sustaining "dead" loads at low temperatures, but that they do lose, to a very serious extent, their power of sustaining shocks or resisting sharp blows, and that the factor of safety in structures need

not be increased in the former case, where exposure to severe cold is apprehended, but that machinery, rails, and other constructions which are to resist shocks, should have large factors of safety, and should be most carefully protected, if possible, from extremes of temperature.

It will be noticed that nothing in the evidence here quoted indicates crystallization or any change of molecular grouping to be consequent upon simple change of temperature.

STEVENS INSTITUTE OF TECHNOLOGY,
HOBOKEN, N. J., May, 1873.

ON RECENT IMPROVEMENTS IN MILITARY BREECH-LOADING RIFLES AND AMMUNITION.

BY CAPTAIN O'HEA.

From "Journal of the Society of Arts."

Although the years which have passed by since 1869 have been more remarkable for modifications and improvements in existing systems—for the discovery of defects, and in some instances, for their correction, than for inventions, nevertheless these years have not been altogether barren of novelty; more than one invention of merit and promise has appeared.

On the previous occasion, I broadly divided my subject into the Ammunition and the Arm, giving precedence to the Cartridge. I see no reason why I should depart from this order to-night; on the contrary, three years of experience have rendered me more satisfied than ever that the ammunition is the premier division of the subject on which I write. Without proper ammunition the weapon would be worthless as a fire-arm; and even in a mercantile point of view, a small arm of our time fires away in a few years—and in many cases in a few months—more than three times its value in the cost of ammunition. I shall not then depose the Cartridge.

The past three years have not been remarkable for improvements in the gunpowder ammunition for breech-loading small-arms; while one of the best, if not the very best, British metallic cartridge—that which gained the Government prize of £400 in the cartridge competition—has become, I regret to say, difficult to obtain. One or two modifications of existing systems have been put forward; I am not, however, in a position to say that they are improvements; nevertheless, although the time has been unprofitable as regards improvement, it has not been so as regards information on the subject of ammunition. In this comparatively short period a great European war has been fought out, the first in which the breech-loader has been used against the breech-loader, both the armies engaged having also used, to a large extent, the paper-cased ammunition. The subsequent rejection of this system of cartridge by both armies, and their adoption of the metallic re-loading case, afford the strongest evidence of the superiority not only of the metallic cartridge, but also of the system which furnishes facilities for reutilization.

Before leaving the subject of ammunition, I would offer a few brief observations on the metallic cartridge for breech-loading small-arms, in particular on the cartridge in general use in this country with small-bore arms. In so doing I must, to some extent, repeat what I stated here on a former occasion.

With reference to the case, it is now, I believe, acknowledged—all other conditions, save the primary cost of manufacture, being equal—that the cartridge-case which can be reloaded the greatest number of times, in the simplest, readiest, and least expensive manner, is the best—the primary cost of the case being reduced in proportion to the number of times it can be re-utilized, the weight of the case also being taken into special consideration. Not many years ago a certain number of soldiers per company had, by our Musketry Instruction, to be trained to the manufacture of cartridges for the Enfield rifle. Might not the practice as regards refilling the metallic case be continued, with advantage to the service and to the revenue? I would suggest that there might be instances of troops being temporarily shut out from supplies in a detached position, when, having expended their supply of the loaded metallic cartridges, the practicability of reloading the

case might be tantamount to the holding possession of the post.

I would further remind the best marksmen in the world—the Volunteers of England—that if the cartridge-cases which they extract and throw away in such large quantities annually were capable of being returned to store and re-utilized as ball ammunition, instead of being sold as waste metal, it would be a considerable saving to those who expend so much ammunition in the year.

With respect to the powder charge, the greater the powder power which, in a given length and diameter of bore, can be utilized to propel a projectile of defined weight, the greater the initial velocity—convenience to the soldier, as regards recoil, etc., being duly considered. The greater the initial velocity the flatter the trajectory, and, as a consequence, the longer the dangerous space; and the military arm giving the flattest trajectory to the longest distance *must* be the most efficient; for, all other points being equal, there is a gain in vertical accuracy, and, as a consequence, a diminution of the chance of error in judging distance.

With regard to the projectile: Without referring to the best form (on which Major-General Boileau, R.E., is unquestionably one of the best authorities) or to the component material, further than to remark, that the harder the material of the projectile the better, especially for penetration, I would venture to offer a few suggestive remarks, the result of practical experience, during the past few years, of many thousand rounds of ammunition.

In the first place, it would appear to have escaped special notice, but it is nevertheless a fact, that to impart to the projectile in its after-flight the rotation due to the pitch of rifling in the bore from which it is fired, it is not at all necessary that the metallic surface of the bullet itself should be compelled to take or conform to the rifling. On the contrary, the indenting or defacing of the surface of the projectile, by means of the rifling in the barrel, becomes materially injurious in its after-flight and detrimental to its penetration. All the rotation due to pitch of rifling can be obtained with equal certainty by the medium of a proper system of paper or other wrapping on the bullet. The projectile of the Prussian needle gun (*Zundnadelgewehr*) never touches the barrel from breech to muzzle; it is carried along the rifling and receives rotation by means of the *sabot* in which it is seated. I have used bullets which, without any wrapping, passed through the rifle bore without receiving the slightest mark or indentation from the rifling, but which, when fired enveloped in tough paper, gave all the accurate results obtained from the rifled bullet. I have recovered, in an almost uninjured state, a large number of the Henry projectiles used with the Government small-bore ammunition, and on almost all of those so recovered there is scarcely a mark of rifling in front of the cannelure, and in many instances not a mark of rifling even below the cannelure. I would, however, remark, that, to really utilize the tough paper (or other slight substance medium), for the purpose of rotating the projectile, a fine description and a blunt pattern of rifling ought to be adopted. Rifling of a sharp angular pattern is likely to cut the wrapping instead of indenting it, and thus becomes detrimental to accuracy of after-flight.

Again, I would draw attention to the curious misapplication of our national rule of weight in the case of the small-bore projectile adopted by the Government, and in general use with the small-bore breech-loaders of this country. The weight of the projectile is 480 grains—1 oz. troy, or apothecaries' weight. Now, as lead and all other metals except gold and silver, are weighed by avoirdupois weight, if the national ounce bullet is to be retained, might it not be well to make it 437½ grains, or the ounce avoirdupois? That this could be done without any lessening of accuracy, even to a longer range than 900 yards, I can assert from experience.

I will now refer to the arm, the engine by means of which the power stored up in the cartridge is utilized, and to the improvements which have been brought forward during the past three or four years.

The arm I shall, as before, divide into the breech mechanism, the rifled barrel, and the mountings.

I would remind you that the breech action of a small arm is the means by which the loading of the arm, the firing of the cartridge, and the extraction of the case are effected; in fact, the action is the means of assisting and facilitating the manipulation of the arm; and that action which affords the greatest and most perfect assistance, combined with safety, is the best.

The rifled barrel is the means by which

the projectile receives initial direction, and the rotation round its axis of progression necessary for steadiness in after-flight.

The mountings are intended to facilitate the handling of the arm; in some cases they add to the general appearance and strength of the weapon, but they very often impair its efficiency.

Under the separate heads of block and bolt action, I shall, to-night, refer to late improvements in the breech mechanism.

In the block-breech mechanism there are five distinct classes, but I shall only speak of three:

1. The rear-hinged or pivoted dropping block, of the American Peabody class.

2. The vertical sliding or wedge block, of the American Sharpe class, represented in this country by the well-known Henry, which, in connection with the Henry rifled barrel, obtained the Government prize of £600.

3. The side-hinged swinging block of the Snider class.

Of the other two classes, namely, the front-hinged block turning over on the barrel on the Mont-Storm plan, and the top or balance-lever block of the Money-Walker class, there may be recent modifications, but they have not come under my notice.

Of the first class, without any wish to ignore others of merit, if such there be, I ask your attention to four modifications.

In point of time of production, the Tranter stands first; this, like every arm brought forward by Mr. Tranter, of Birmingham, bears the stamp of much mechanical ingenuity and first-class manufacture.

Next, the Zeller, a clever modification by Zeller, a gun maker of the Hague, of the Bavarian small arm, in which, by means of a second trigger placed inside the trigger-guard, the full and half cocking of the arm is accomplished without the necessity of using the lever or moving the block. The main spring is also noticeable in this action.

The next is the Harston, the modification of C. Greville Harston, of Birmingham, for which the patentee claims, in addition to simplicity of construction, etc., increased safety in using the rifle, from the fact that the action has three points of resistance to the discharge instead of one—viz., the hinge of the block, the lug of the lever engaging with the lug of the block, and the hammer, when the arm has been discharged.

And, lastly, the Swinburn, patented within the last year, a very clever modification of the Martini, for which, among others, the patentee claims the following advantages: Great reduction of wear and tear upon the working surfaces, in consequence of the main-spring offering no resistance to the closing of the breech; a lighter main-spring by 50 per cent. than the Martini, giving greater certainty of fire; the use of a safety half-cock, dispensing with the complicated safety bolt, and placing the firing apparatus under control of the person firing, independently of the breech-closing apparatus; and finally, a pull-off of trigger capable of being regulated and made as easy as that of a sporting rifle; a more powerful extractor, and a considerable lessening in number of pieces.

In the foregoing, the avoidance of the use of a spiral spring as a main or driving spring, and the adoption of the old or ribbon mainspring, will be noticed; a waste of power in compression and propulsion is avoided, and the light or medium pull-off, absolutely essential to accuracy of shooting, obtained.

Of the vertical sliding block there have been two or three modifications, but I trust I may be excused for introducing only one to your notice, the Aston, the invention of Mr. Aston, armorer to the School of Musketry at Hythe. An examination of this breech-action will well repay those present who take an interest in mechanism of an ingenious and very simple character. I would only remark that in the Aston action there are ten parts or pieces, as against thirty in the Martini.

The rifle has a block action, fitted with two flat springs. It cocks when opening the breech. There are two bents for full and half cock. The hammer, in striking the cap, moves a quarter circle, doing away with the usual piston and spiral spring, and is not so liable to miss fire with a light spring. The breech is opened and closed by a lever on the right side; there are no projections above or below when the rifle is opened or closed. It is easy to strip and put together, and not liable to get out of order. The barrel can be cleaned from breech or muzzle. In the construction of the rifle all projections have been avoided. It is a simple action, with very few parts, and can be made very cheaply.

Of the third class, the side-hinged swinging block, I will also mention only one,

the Dunstan. Indeed,I am not aware that any other improvement on this description of block has appeared during the past three or four years. This is really a very clever modification, for Mr. Dunstan, the patentee, not only manages to enclose the limbs or pieces of the ordinary side-lock, in a small swinging-box block, but he uses a safety thumb-pressure trigger, by means of which he claims, with reason, to lessen the disturbing influence to accuracy attending the pull of trigger as usually used in the small arm.

The bolt system of breech-action has not been the subject of much modification or improvement of late years. The Chassepot, however, has been or is being modified for the use of a metallic cartridge, and the Prussian needle gun is also being modified on a system called the Mauser.

I feel that I cannot close my description of recent improvements in breech mechanism in a more fitting manner than by introducing to your notice the new Smith and Wesson pistol, a most perfect specimen of the revolver.

More than two years and a half ago the Smith and Wesson pistol was placed in my hands by Mr. William Read, the well-known gun and ordnance manufacturer of Boston, United States, and since that time the arm has been subjected to most severe tests. I have no hesitation in stating that it is the most perfect little weapon of its kind I have ever tried. A detailed description of this arm is unnecessary. The action tells its own tale.

In leaving the subject of the breech-loading action in general, I would offer one or two observations on the pull-off of trigger. The pull-off of trigger is almost as essential to steadiness and accuracy of shooting as careful training, large practice, and good nerve. A long pull, a strong pull, and, above all, an uncertain pull as regards time and pressure, is not the pull-off to sustain accurate and steady shooting. The long retention of the breathing with such a pull-off is positively uncomfortable, not only to the individual about to fire, but to the individual looking on. A pull-off of not more than 5 or 6 lbs., and a sharp and certain release of sear are requisite for accuracy of shooting.

A long reach for pull of trigger is also a certain cause of inaccurate practice. Our musketry instruction teaches us that the finger is to go round the trigger like a hook, while the remainder of the hand holds the small of the butt. Where the trigger is over forward, I would suggest the use of a curved trigger, to facilitate the steady pull or pressure of the trigger.

Before entering on the second division of this subject—the rifled barrel—it might be well to refer briefly to the origin of the rifle—to explain what a rifle really is, and the results attained by rifling.

Originally rifling was used as a system of drainage for fouling of previous discharge in the barrel, to facilitate loading from the muzzle, and the grooves or rifles were straight from muzzle to breech. A gunmaker at Nuremberg is said to have been the first who cut these drains or channels on a curve—it is supposed by accident; but our countryman, Benjamin Robins, in a tract on "Rifled-barrel Pieces, published in 1747, was the first to point out the real effect of spiral rifling on the flight of projectiles propelled by gunpowder. A rifled barrel or tube is literally a female screw—the nut through which a bolt—the projectile—is driven with more or less velocity, according to the power applied to it, and the pitch or form of screw offering more or less opposition to its transmission; and rifling is now used for the purpose of giving rotation to the projectile round its axis of progression, by which more or less steadiness is given to it in its after-flight.

It is not my intention to enter into the history of the rifle. For information on the subject I would refer to a lecture given by me on "Rifles and Rifling," at the Royal United Service Institution, on the 28th March last. My paper to-night has reference to what has been brought forward during the past three or four years. In that period, and, indeed, for many years previously, there has been but one radical improvement, one real novelty in rifling, brought forward. I refer to the invention of William J. Murphy, Esq., of Richmond, Cork. This invention, for it is an invention of an exceptional character, cannot be said to be rifling of a new pattern, since it embraces every known pattern; nor can it be referred to under the head of pitch, as it is applicable to pitch of any and every degree.

The peculiarity consists in rifling, with *inclined* rifling, only a portion of the bore—a comparatively small portion—towards or at the muzzle, the rifling being dispensed with in a large portion of the bore in front

of the seat of shot, where it has hitherto been an impediment to the initial motion of the projectile, and consequently a cause of recoil. The peculiarity and novelty of the system consist in some measure in confining the rifling, not only to that portion of the bore where alone (as I have proved by experiment) rifling can be necessary, but to the very portion of it which has hitherto been considered the weakest; where, in fact, we have been taught to believe that any impediment to the free exit of the bullet would involve the destruction of the arm.

The patentee claims for his system the following advantages: first, a great reduction of recoil, without any reduction of charge or increase in the weight of the arm. Secondly, increased velocity of projectile and consequent flatness of trajectory, without any loss of accuracy of direction. Thirdly, from the position of the rifling, facility for punching, drawing, or cutting, and accurately gauging the same; and, though last, not least, a very considerable reduction in the cost of manufacture, with more exact evenness of pitch and form of rifling, consequent mainly on the small portion of the bore that will be rifled.

Mr. Murphy contends that the fact of the surface of the projectile having to travel along the incline of the rifling towards or near the muzzle, retards only slightly, without unduly checking, the velocity at that point, and that in consequence a larger quantity of the powder-charge is consumed, and a somewhat greater power is thus finally applied to expel the projectile from the bore than with the ordinary rifle. In the case of this latter, the increasing velocity of the projectile is unimpeded, save by the column of air in the barrel, until it escapes from the muzzle, except when increasing pitch is used.

In August, 1871, Mr. Murphy placed his invention in my hands, and since that date I have subjected the system to extended trials with many arms having rifling of various patterns and degrees of pitch. My experience with these rifles, which extends to the firing of several thousand rounds of ammunition, enables me to state that the claims of the inventor have been borne out, to an unusual extent as inventions go; and this, too, under the difficulties attending primary manufacture, and a supply of ammunition of the most faulty and uncertain description that I have ever used, the only supply open to me.

With a Martini Henry rifle, bitted out to within 4 in. of the muzzle, using the regulation cartridge, I have at 400 yards obtained very satisfactory shooting with elevation for 275 yards only; at 500 yards with elevation for 350; at 600 yards with elevation for 400. With a barrel rifled on Mr. Murphy's rib system, having the same length of rifling as above, I have, also with the regulation cartridge, at 500 yards got good targets with 400 yards elevation; at 600 yards, with sighting for 450; and at 700 yards with elevation for 550. With a Peabody-Murphy, the trajectory flattens in like ratio as with the last named arm, as you get further from the target. With a Henry barrel attached to a Westley-Richards breech-action, using the Westley-Richards cartridge (76 grains powder, 480 grains projectile), I have got equally good results as regards trajectory, with extreme accuracy of direction. Lastly, not to weary you with a further account of experiments, I have, with a Navy Enfield, obtained admirable shooting up to 600 yards, but with less gain in flatness of trajectory, owing to the thinness of the metal at the muzzle.

I cannot hesitate to express my conviction—a conviction founded not on theory, but, as I have said, upon extended practice—that rifling barrels all through, from the seat of shot to the muzzle, is, for all the advantages that rifling is intended to secure, unnecessary, and simply a waste of time, metal, and labor—which means money; and I have every confidence that when the Murphy principle is known, and the system fully and fairly tested, this arm will find its place.

I would add, that I have fired more than 100 rounds per barrel at a time, from nearly all the barrels converted on this system, without cleaning, and without having a strip, or failure as regards vertical accuracy. Of course, like many others, when I first commenced testing this system, there were failures, and bullets left the bore without taking the rifling.

With reference to the last section of this division, I will offer but one brief remark. Bands on a barrel are, to a certain extent, detrimental to even expansion, and consequently to accuracy. To all who use a divided stocked arm, this must be evident. The bands, as well as the half-stock, of the Martini-Henry, have to be pinned, in order to prevent their being carried away over

the muzzle by the wave of metal consequent on the passage of the bullet up to the bore; and, besides, this fastening on necessitates the fixing of an additional lump of metal on the surface of the barrel.

ON MOISTURE IN FORESTS.

From "Iron."

The climate of a place is determined by temperature and by moisture. In order to understand the influence of forests upon a climate we require to ascertain in what way they affect both these factors. A few weeks ago we gave the results of a series of experiments (at seven stations in Bavaria) by Herr Ebermeyer, the object of which was to determine the influence of forests on *temperature*. The following are the views to which the same observer has been led with reference to *moisture* in air and soil:

The absolute moisture of forest air appeared, in the course of a year, to be, on the whole, hardly greater than that of air in the open field In the individual seasons, also, and months, the forest seemed to have hardly any influence on the absolute quantity of moisture in the air.

It was otherwise, however, with the relative moisture, which is of more practical interest. As the temperature of air in the forest is, on the whole, lower than that in the open field, the forest air must, with the same absolute moisture, have a greater relative moisture than that in the open. The former is nearer its point of saturation, and a determinate lowering of temperature will therefore produce a separation of water more readily, and in greater quantity, than in the open.

This difference of relative moisture is much more marked in high lands than in low lands; quite corresponding to the increasing values of the difference of temperature between forest air and open air as you rise above the sea level. Farther, because the difference of temperature is greater in summer, the relative moisture of forest air in summer exceeds that of the open air by a greater amount than in the other seasons of the year.

The forest thus makes the climate moister, and more in summer, in the time of vegetation, than in other seasons. The difference of relative moisture between forest air and that in the open was—in spring 5.70 per cent.; in summer, 9.28 per cent.; in autumn, 5.22 per cent.; and in winter, 5.24 per cent.

The greater relative moisture of air in the forest must, like the lower temperature, affect the amount of evaporation. Observation was made of the quantities of water evaporated from a free water surface in forest and in the open field; and it appeared that, on an annual average, the evaporation is about 2.7 times, or 64 per cent., smaller in the former than in the latter. On comparing seasons, it appears that here also the influence of the forest is greatest in summer; it was nearly 4 times as great as in winter. But even in winter there was evaporated, on the other hand, 2½ times less in forest than in the open. As the difference of temperature between air in the forest and that in the open is very small, the lower temperature cannot alone be the cause of the smaller water evaporation; this is probably conditioned, in great part, by the much weaker motion of air in the forest.

It is instructive to study the amount of evaporation from a free-water surface in the individual months. We learn that in no month did the water evaporation in the forest reach that in the open. The difference in the warmest and dryest months, July and May, was on an average 290.28 cubic inches water per sq. ft. of water surface. The smallest difference was in November, being only 49.17 cubic inches. If, however, we turn from the absolute quantities of water evaporated in forest and open, and consider the relative proportion, *i. e.*, if we ascertain the numbers which express how many times the evaporation in the forests was smaller than that in the open, we find that this relative proportion does not essentially alter in the several months, and that, in the forests, on an average, two to three times less water is evaporated than in the open.

Of greater practical interest than the evaporation from a free water surface is that from the ground. This was at the various stations, measured directly; only in

the summer half of the year, indeed, as in winter, the apparatus was liable to injury, in consequence of the freezing of the ground. Not only forest and open field were compared with each other, but the influence of litter-covering (*streu decke*) was examined. The results were as follows:—

The forest alone, without litter-covering, diminishes the evaporation of ground-water (as compared with that in the open) about 62 per cent.; the evaporation is about 2.6 times less in the forest than in the unwooded ground. With litter-covering, the evaporation of ground water was farther diminished (as compared with the open field) about 22 per cent., being about 1.3 times less. Forest and litter-covering together diminish by about 85 per cent. the evaporation of ground-water. In litter-covered forest ground, the evaporation of ground-water is about 60 per cent., or 2.5 times less than in forest ground without litter. The important influence of litter-covering on the evaporation of the moisture in the ground is thus apparent.

The influence of the forest on meteoric precipitates comes next to be considered, and from two points of view. It is desirable to know how much of the falling rain and snow reaches the ground in a forest as compared with an unwooded surface, *i. e.*, how much of it is intercepted in the upper parts of the forest trees. Another question is: What influence have forests on the quantity of rain in a country? Do they favor the formation of rain or not? The Bavarian experiments furnish some information on these subjects.

Comparing the quantities of rain and snow which fell on the open with those which reached the forest ground, it appears that on an average of all the stations, the latter was about 74 per cent. of the former. The tops of the trees in a normal forest thus intercept about 26 per cent., or a quarter of the water precipitates. The inferiority in supply of water to the forest ground, as compared with the ground of the field, is of course, however, smaller, because only a portion of the rain and snow falling on the tree tops is evaporated; the remainder flows down, by branches and stem, into the ground. In forests of proper-leaved trees, the annual quantity of rain and snow which reached the ground was greater than in forests of acicular-leaved trees; which is explained by the fact that in winter the former have no foliage.

Coming to the other question, the influence of forests on the formation of rain and snow, it is at once evident that several other influences or "moments" affect the quantity of meteoric precipitates, and must first be eliminated. First among them is that of height above the sea level. Of the two stations—Rohrbrunn and Aschaffenburg, only four hours distant from each other, the former lies 1,067 ft. higher, and here the annual rain and snow-fall is about 38 per cent., or more than a third greater than in Aschaffenburg. Farther, Rohrbrunn has, on an average, 166 rainy and snowy days; Aschaffenburg only 142. Not less important, in the formation of rain, is the site, and the prevalence of certain winds at particular stations.

Herr Ebermeyer's results lead him to affirm that in plains of the same general character, the influence of forest on quantity of rain is very small, and that it has also no marked influence on the percentage distribution of rain. With elevation above the sea-level, the importance of the forest, as regards influence on rain quantity increases; on mountains it has a higher value than on plains. In the summer half year the action of the forest on the rain quantity is much greater than in the winter half year.

If we compare the precipitates falling on the square foot, with the quantities of water evaporated from an equal free water surface in forest and in the open field, it appears that, almost everywhere, the annual rainfall was greater than the evaporation; at one station only there was more evaporation, in the open field, than rain. The higher the place is, the greater is the excess of rain and snow water over the quantity of water evaporated. In the interior of a forest the evaporation is so small that a much larger quantity of water reaches a water surface, and, of course, also the ground, than is dissipated by evaporation.

As in a forest, about 26 per cent. less of the entire rain quantity reaches the ground than in the open field, it might be expected that the quantity of water which passes through the forest ground would be smaller than that through the unwooded ground. This is not, however, the case. Cylindrical lead vessels of 1 ft., 2 ft., and 4 ft. depth, having a sieve bottom, and filled with earth, were so buried in the forest and in the open, that their edges was nearly level with the surface. Under each sieve was a

load funnel and tube by which the water passed into a trench, from which it was afterwards removed in graduated vessels. There passed through the litter-covered forest ground, per 3 sq. ft. of surface, about 152 cubic in. more water than in the open field; the difference was most marked at 2 ft. depth, and thus, generally, in the root region of the trees, where the quantity of water which passed was, on an average, 457 cubic in. greater than in the unwooded ground. Evidently the smaller quantity of precipitates in the forest is more than balanced by the less evaporation from the forest ground.

For agricultural purposes, it is important to ascertain the quantities of water which pass through the ground in the several seasons; and of special interest is the behavior of field and forest ground, with reference to water, during the time of vegetation. The mean numbers of all observations show that in the open field most water penetrates the ground in winter; next comes spring, then autumn, and last summer. The difference between summer and winter is very great. In summer, when evaporation is greatest, the quantity of water which passed through was at 1 ft. depth, $3\frac{1}{2}$ times; at 2 ft. $4\frac{1}{2}$ times; and at 4 ft. $7\frac{1}{2}$ times, less than in winter. The forest-covered ground behaves towards water quite differently, and the litter-covered ground is again different from that without litter. In forest ground without litter-covering, the quantity of water at 1 ft. depth is greatest in winter, then follows spring; and in autumn and summer it is nearly equal in litter-covered forest ground; the quantities of water penetrating in all the four seasons were nearly equal.

If we compare the forest ground with the open field, the quantity penetrating the former is, in winter, less than that penetrating the latter. In spring, the forest ground at 4 ft. depth, gave, per 3 sq. ft., about 133.42 cubic in. more water than the unwooded ground. In summer, litter-covered forest ground gave, at 4 ft. depth, 1245.71 cubic in. more water, per 3 sq. ft., than the ground in the open; while in forest ground without litter, at 1 ft. depth, twice as much water passed through as in the open. In autumn, lastly, the penetrating quantities of water in forest and in field were nearly equal. The action of the forest and of litter covering, on the water contents of the ground and on the humidity of a region, is thus most marked in the warmest season, and in hot countries. The forest produces an equable distribution of the ground-moisture in the several seasons of the year.

From the foregoing observations, the influence of forest on vegetation and on water springs, might be readily deduced.

ONE HUNDRED MILES AN HOUR.

From "The Engineer."

It will scarcely be disputed that to possess the power of traversing long distances at a velocity of 100 miles an hour would be advantageous to a very large section of the community. The average speed on the best mail coach lines in 1829 and 1830 was a little over 10 miles an hour; and many individuals possessing the power of thinking clearly and writing well, argued that no augmentation of mail coach speed was necessary, desirable, or likely to produce any benefit to the nation. The advent of railway speeds sufficed in a very short time to prove that all arguments of this kind were fallacious. In 1830 speeds of 30 miles an hour were regularly attained by railway trains, and the advantages to be derived from this rate of travelling were quickly and keenly appreciated by the public. In the same way and for the same reasons, it is certain that the benefits to be gained by the power of reaching Liverpool in two hours, or Vienna, for example, in twelve hours, would be quickly recognized by the nation; and it is probable that a sufficient number of passengers, at considerably higher fares than those which are now paid, would be obtained on any great main line to justify directors in putting on one or two extra trains in the day which would maintain when running an average velocity of 100 miles an hour. How much the public would be content to pay for such a privilege it is of course impossible to say with accuracy; but we believe there is a fair probability that trains travelling at 100 miles an hour could be made to pay, provided the cost of running them was not

enormously in excess of the cost of running an ordinary express train timed, say, at 45 miles an hour. In considering the subject, this question of cost is one of the most important features to be dealt with. A more important question, however, is this:—Is it possible to attain, or, having attained, to maintain, at any price whatever, or under any conceivable conditions, a velocity of 100 miles per hour? This question must be settled first, as it would be absurd to attempt to calculate the cost of an impracticable undertaking.

The highest railway speeds in the world are attained in England, and the highest railway speed in England is attained on the Great Western Railway, and this speed may be taken roundly as 50 miles an hour. But this by no means represents the maximum velocity which can be reached in running with a powerful engine and a light train on a good line. There is a tradition in existence that Brunel once travelled from Swindon to London at 80 miles an hour; but we have never been able to obtain a shadow of proof that this speed has been reached under any circumstances or at any time whatever on a railway. Mr. Stirling has run with one of his great outside cylinder express engines and a train of 16 carriages at 70 miles an hour on the Great Northern, on a level or with a slightly falling gradient; and we know that the Yarmouth express on the Great Eastern sometimes has reached a speed of 64 miles an hour down the Brentwood bank. On two occasions some years ago, in Ireland, we ran 14 miles in 16 minutes with a powerful engine and a train of but two carriages. Much of the run was done at over 65 miles per hour. On the Boston & Albany road, U. S., the 54 miles between Springfield and Worcester were run by an engine with 16 in. cylinder, 22 in. stroke, and 6½ ft. driving wheel, in 58 minutes. Much of the run was done at nearly 70 miles an hour. On a first-class line there can be no question, therefore, that a speed of 65 to 70 miles an hour may be available with safety. It is doubtful, however, whether a much higher velocity, such as 100 miles an hour, would also be available without incurring enormous risks of derailment. Brunel proposed at one time, when a line was laid on stone sleepers or piles, to take a truck over it with two revolving grindstones in front which should grind the rails to a dead smooth face. His ideal of permanent way was a lathe bed. We know now, and Brunel lived long enough to know also, that many of the ideas he entertained in the early days of his career were chimerical. But we none the less believe that it would be possible to lay permanent way so well, and to maintain it in such excellent order, that trains might travel on it with perfect safety at 100 miles an hour. Miles upon miles of such track are to be found now on most of our great main lines, but it is not to be disputed that nowhere can 100 consecutive miles of permanent way in perfection be found, and as a chain is no stronger than its weakest link, so a few hundred yards of bad track would spoil for the purpose of travelling at 100 miles an hour a whole line. It would not be impossible, however, to maintain a line of such rails from London to Liverpool or York. First-rate ballasting would be required, and the rails would be best constructed on Ashcroft's system, that is to say, with a steel head laid between two iron cheeks, so that no fish-plates, nor any joints in the ordinary sense of the word, would be used. The rail would, of necessity, be of great depth to insure rigidity, without which the resistance would be so augmented that the required velocity could not be maintained. It is scarcely necessary to add that steep inclines would be absolutely excluded by the conditions.

Let us assume that a line, good, safe, and rigid enough for a speed of 100 miles an hour is to be had. That, in fact, it is provided ready to the hand of the mechanical engineer—the man who has to design the rolling stock to work it—and proceed to consider what this rolling stock must be. It is obvious that the carriages should be as light and strong as possible, and we shall content ourselves with this statement regarding them for the present. The really important question is, given the line and the carriages fit for it, what shall the engine be like, and is it possible to construct an engine at all which, with a moderately heavy train, will attain and maintain a velocity of 100 miles an hour, on a line with no grade heavier than say 1 in 300. The first points to be settled are, how much power can a locomotive of a given size develop, and how much power shall we require to haul a train which will suffice to satisfy the demand of that portion of the public wishing to travel at 100 miles an hour? Let us assume that the train will consist of three

first-class carriages and a brake van, the carriages weighing each 8½ tons and the van 10 tons, or in all, say 35 tons. No experiments whatever have been made with trains travelling at a speed of 100 miles an hour, and it is therefore impossible to do much more than guess at the probable resistance to be overcome. At 60 miles an hour on an ordinary line, and making due allowance for contingencies, it cannot, according to experiments carefully carried out both in France and in this country, be much under 40 lbs. per ton. At 30 miles an hour the resistance is about 20 lbs. per ton; at 47 miles an hour the resistance reaches 32.5 lbs. If the resistance goes on increasing in this proportion, then the resistance at 100 miles an hour cannot be less than 75 lbs. per ton; but it may be very much more, and it would not, we think, be safe to take it at less than 120 lbs. per ton. Now a speed of 100 miles an hour is 146.5, or in round numbers, 146 ft. per sec., or 8,800 per min. This multiplied by 120 and divided by 33,000, gives, say 32 horse power. Therefore each ton moved at 100 miles an hour will represent 32-horse power. The "Great Britain" broad-gauge Great Western engine, with its tender, in running order represents a weight of about 64 tons, and a heating surface of 2,100 sq. ft. This engine has indicated over 800-horse power. To run such a machine and a train weighing 35 tons, or a gross load of 99, or, say, in round numbers 100 tons at 100 miles an hour, would require 100×32 or 3,200-horse power, or just four times more power than the most powerful high speed locomotive that has ever been built could exert. To run the engine, weighing 38 tons, alone, would require a power of 1,216 horses, assuming that the engine resistance was identical with that of a carriage. These figures suffice to prove that it is absolutely impossible to obtain a speed of 100 miles an hour on a railway if the resistance is anything like 120 lbs. per ton.

It will be seen, then, that the whole question may be narrowed to one point, and that point is train resistance. It is little more than waste of time to discuss any other question connected with the matter, such as safety and working expenses, until it has been settled whether it is or is not possible so far to reduce resistance that it will become possible to construct an engine of sufficient power to fulfil the intended purpose. Many improvements have been effected in the construction of locomotives since the Great Britain was built, but we shall be going almost too far if we take it for granted that an engine can be constructed which will weigh in running order 30 tons only, and yet be able to develop 1000-horse power. It is probably not possible to construct such an engine. Now 1000-horse power represents 33,000,000 foot-pounds per min. If the resistance is to remain equivalent to 32 or 33-horse power per ton, it follows that the maximum load that 1000 horse-power could transport at 100 miles an hour is only about 32 tons. As, however, the engine alone would weigh 30 tons, next to nothing is left for coal or water, to say not a word about passengers. With a 60-ton engine it is doubtful if we should have much more margin of power than would barely suffice to carry a very limited supply of water; certainly nothing like enough for even a ten minutes' run, and as Ramsbottom troughs could not be laid down everywhere, the scheme would break down at once, simply on the ground that water enough could not be carried.

If it can be shown, however, that the resistance could be brought much below 120 lbs. per ton, then it may be possible to attain a velocity of 100 miles per hour. A train of 16 carriages and a Great Northern Express engine may be taken to represent 180 tons. At 70 miles an hour, let us suppose the resistance to be 40 lbs. per ton, or 72,000 lbs. Seventy miles an hour is 6,160 ft. per min. and $\frac{7200 \times 6160}{33,000} = 1344$-horse power. It is extremely improbable that any locomotive on the Great Northern ever exerted so great a power as this, and we are therefore led to believe that when Mr. Stirling obtained a speed of 70 miles an hour it must have been under such conditions that the resistance was less than 40 lbs. per ton. The end would be secured, of course, if the engine and train were descending a moderate incline; but it is also possible that under any circumstances of grade the resistance may have been less than 40 lbs. per ton. We have stated that it would hardly be safe to assume that the resistance at 100 miles an hour would be less than 120 lbs. per ton; but it must be borne in mind that this statement is only based on a somewhat weak line of reasoning based on analogy.

It is known that train resistance in-

creases in a very rapid ratio with the speed; but as experiments at such speeds as we have spoken of—that is to say, 70 or 100 miles an hour—have never yet been made to determine the precise resistance, it is quite impossible, as we have pointed out, to say with precision what the true resistance is. And besides all this, it must not be forgotten that as the evil influence of small imperfections in a road is greatly magnified as the velocity increases, so it is possible that the resistance on a road rigid and even enough to be run over safely at 100 miles an hour, might be enormously less than the resistance of what is known as an ordinary fair road. This is a very important point, to which we shall return at another opportunity. Meanwhile we may say in dismissing the whole subject for the moment, that there is good evidence in support of our assertion, that it would not be safe to take the resistance at 100 miles an hour on an ordinary railroad at less than 120 lbs. per ton, in the fact that there is no recorded instance of a locomotive engine, whether with or without a train, ever having run at a greater velocity than a little over 70 miles an hour.

THE VITALITY OF A SUBMARINE CABLE.

From "Engineering."

One of the most important problems of the present day, whether in respect to political, social, or commercial aspects, is that of the maintenance of telegraphic communication by means of the submarine cable. The recently frequent break of passage has naturally given rise to much anxiety on this subject, and its financial consequences have already been discussed in "Engineering," but we believe that we have much underrated the results which might practically arise from causes to which we now allude.

A submarine cable is liable to numerous influences, some of which are greatly in its favor, and others equally to its disadvantage. But our knowledge on all these points leaves much to be desired in regard to really accurate information. Mechanical, chemical, and numerous other conditions are involved, and in no case, so far as our experience has guided us, has any indication been afforded which would lead to a solution of this difficult problem.

A submarine cable is really composed of two or more substances, having in most cases highly different physical characters. Leaving out the question of the external coating of iron or steel wire, we have to deal with the conducting and non-conducting material of which the cable is composed. But to use the "philosophical ideas" of the present day, we have also to deal with two substances, in one of which (the insulator) induction or conduction takes place slowly, while in the other (the conductor) the induction or conduction takes place rapidly. This definition is simply a paraphrase of the laws which Faraday enunciated in 1854-55, and which have since become the basis of all the present systems adopted in submarine telegraphy.

But more recently it has been discovered that motion is a source of all our forces, whether they be heat, light or electricity, and on this point we rest our opinion of the possible, or rather more probable deterioration of any or all of our submarine cables. The leading philosophers of the present day have endeavored to show that without motion, or, in other words, the transition of matter from one place to another, however small the interval may be, no sign of force can be manifested. Without assenting to this proposition, we admit it for the sake of argument, simply because the results we have experimentally arrived at lend a certain amount of countenance to this view.

In 1855 we mentioned to Faraday that we had long noticed wire, of the then purest copper, becoming gradually brittle through the transmission of electrical currents of comparatively high tension. Two wires, each of one-tenth of an inch in diameter, were employed to convey the current of 80 cells of a Grove's battery, the platina plates of each of which exposed an individual surface of 64 sq. in. In the course of a comparatively short time those wires became so brittle as to be readily broken by the fingers. About the same time we received several of then so-called Rhumkorff's coils, now *inductoria*. The terminals of the secondary coil, whether formed of platina, silver, or copper, soon became so

brittle as to be readily broken. To test how far the effects of highly *intense* currents caused this brittleness, we instituted experiments with the hydro-electric machine, then in the Polytechnic Institution in Regent street, and pursued such experiments for a period of about six months. The results were precisely similar. The connecting wires employed between the steam boiler and twelve large-sized Leyden jars indicated that intense electricity had the effect of rendering even the best copper wire brittle.

A microscopical examination of the fractured wire showed that the metal had undergone a change from the fibrous to a crystalline, if not a crystal structure, which was quite sufficient to account for fracture; for of course its tenacity had been diminished. It is well known that the shafting in our manufacturing establishments, and the axles of railway carriages, etc., undergo precisely the same change—that is, from the fibrous to the crystalline or crystal state. Consequently a register is kept of the mileage; and after a certain period a system of annealing is adopted by which the crystalline structure is supposed to be converted into that of a fibrous character. We have seen a specimen of shafting, which had borne for about 20 years a strain of 30-horse power daily, that, having suddenly broke, presented a distinct *crystal* structure resulting from continuous motion.

Our present method of electrical agency in regard to the working of submarine telegraph cables induces, in our opinion, precisely the same results, and this was pointed out several years ago in "Engineering." As to the facts there can be little doubt, for they are easily verified. The remedy, however, seems at present very problematical.

We have chiefly one suggestion to make, which is that it may be possible, by a systematic reversal of electric currents, employed in submarine telegraphy, to effect a partial restoration of the fibrous character of the conducting core. In other words, it would become desirable to find out some method of re-annealing that core by electricity in place of heat. It is a remarkable fact, although, perhaps, one little known, that the platina of a Grove's battery and the silver of Smee's cell both become brittle by constant use. One rule in respect to the platina of a Grove's battery has long been to make it red-hot before use. Two results thus accrue. All saline matter, and the air-coating, are removed, together with its brittleness. Of course this is impossible in regard to submarine cables; but some means may be found out by means of which the evils to which we have referred may be obviated, and if discovered their value would be inestimable.

In lengthened experiments in adapting voltaic or magneto-induced electricity to exploding powder beneath water, cases have been met with in which the use of intense currents has rendered the conducting wires useless through fracture. It is found convenient, too, to use instead of *wires* for all electrical experiments, narrow strips of sheet copper, repeatedly exposing these to a red heat to prevent the results already alluded to.

We do not wish to put too strong a construction on the views and facts that have been here stated. Experience, both as regards inland and submarine telegraphy, is too large to allow us to dogmatize on any point. We rather prefer to ask the aid of our readers for the benefit of their experience in bringing an important question to its proper bearing and perhaps final solution.

THE COAL QUESTION.

From the London "Mining Journal."

The announcement that the Committee appointed by the House of Commons to inquire into the cause of the late panic in the coal trade had determined to take no more evidence, will be received with the reverse of regret, seeing that for all practical purposes the information elicited from most of the witnesses was foreign to the issues to be tried. In fact, the relevancy of most of the questions put to the witnesses as to the reason for the high price and scarcity of coal which prevailed in February last bore but a very small proportion to those which actually related to those points. But although the labors of the Committee are not likely to be of a really beneficial

character to the consumers of coal in the metropolis or elsewhere, either by lowering the price of that indispensable article or by insuring a plentiful supply of it, yet some of the evidence given is such as ought not to be passed over without comment. Although significantly enough, we may say, what appeared to some of the Committee as of the least consequence to practical men was looked upon as of the most importance. To those who have paid attention to the subject of our coal supply, especially to the metropolis, it has long been known that the question of railway carriage was intimately mixed up with it. We, therefore, consider that Mr. Stanhope, one of the Committee, touched a rather vital spot when he stated that, although a colliery owner, he could not send coal from his own pit by railway to his town residence unless through an ordinary dealer. Now, Mr. Stanhope is not only the lessor of some very extensive coal fields now being worked in South Yorkshire, but has also a colliery of his own from which his country mansion, Cannon Hall, is supplied. Yet with an abundance of excellent coal he is compelled to pay fully £1 per ton more for an inferior article in London than he would otherwise have to do, because the railway company grants a monopoly to the metropolitan merchants. Here, then, we have one of the causes for the high price of coal which prevailed during the early part of the year. We, therefore, much regret that the Committee did not carry the railway question much farther than it did, for a great deal of most valuable information in connection with it could have been given.

As an illustration of the existing railway monopoly with regard to the coal traffic, we may state that the coal-owners of South Yorkshire for years past have been endeavoring to obtain a line of railway from their vast mineral fields to the metropolis, so as to be independent of the Great Northern, but without success. In 1864 a line was promoted from Doncaster to Peterborough to join the Great Eastern, when it was proposed that the coal should be carried to London at ¼d. a ton per mile. The Bill was opposed by the Great Northern, and thrown out by the Committee of the House of Commons on the ground that the carriage rate for coal as proposed would be unfair towards the former costly line. In 1871 another proposal was made for a mineral line to carry coal at about the same rate as the previous one, but, being opposed by the Midland and Great Northern, met with the fate of its predecessor. During the present session a third effort was made for a new line, but with like success; it was killed in Committee. On those three occasions the various railway companies interested were represented by the ablest Parliamentary counsel, yet no one appeared on behalf of the public of London, to whom the decision was one of cheap or dear coal. This will be evident when we say that the difference in the carriage rate of coal by the two first proposed lines we have alluded to would have been 3s. 6d. per ton in favor of the London consumer over what he was then, and is now, paying. Surely, with such facts there was sufficient groundwork for the Committee to have inquired how far the railway monopoly had affected prices. The omission we do know was considered by many colliery proprietors as a very serious one.

With regard to the working of mines, there was some truth in the remark made by Mr. Normansell whilst giving his evidence, that the more you educate a man the more you unfitted him for hard work. Mr. Smith, the agent to Lord Ward, was evidently thinking of the same thing when he said the effect of recent legislation tended to the extermination of the race of colliers. This is evident from the fact that even now there is more difficulty than ever there was in inducing parents to allow their children to go into mines to work. A large number of colliers, too, give their children at present a good education, and the boys associating with a class rather above them, prefer a more genteel and cleanly profession than that of a miner. But in this we do not see much to grieve at, for it can only hasten the more general adoption of mechanical means for cutting coal, which is so successfully in operation at so many places at the present time. In fact, coal-cutting machines before very long will become an actual necessity, for even now there is a dearth of colliers, and which will be more fully felt in the course of a year or two, owing to the large number of collieries now being opened out in all parts of the kingdom. We were, therefore, surprised to find that the Committee did not take any evidence with regard to machinery for getting coal from those in charge of mines where such is now in use, as well as from inventors whose machines are being worked. Here was another opportunity for obtain-

ing reliable and valuable information on a most important matter relating to mining, and on the future production of our collieries, that was almost entirely overlooked by the Committee.

Mr. George Elliot gave some very interesting evidence on the last day of the sitting with reference to double shifts, and we certainly agree with him in his views that it would be alike advantageous to owners and workmen. The opposition, to our thinking, on the part of the men is in a great measure due to the fact that by such a system the output of coal would be greatly increased. The same gentleman also alluded to a truly gigantic proposal—but one not by any means new—the amalgamating of all the collieries in Durham into one company. No doubt such a vast concern under one management would have its advantages, but in all probability it would be followed almost immediately by a similar combination on the part of the workmen, already a powerful body. We should then have two great powers, capital and labor, like two contending armies, watching most jealously each other's movements, and always kept in a high state of excitement, expecting to have to give battle at almost any moment. The present state of affairs we believe will be found more satisfactory, especially as there will be no difficulty whatever in colliery owners combining together in defence of their legitimate interests, and in being supported in so doing by public opinion, as they were in the recent struggle in South Wales.

Having thus noticed a few of the salient points brought out in evidence before the Coal Committee, as well as those which might have been advantageously entertained, we again venture to reiterate our opinion that all cause for alarm as to the scarcity of coal, or of the price of it being anything like it was in the early part of the year, has passed away. We believe the effects of the late panic will be seen before very long in a vast increase in the production of coal in all parts of the kingdom, owing to the opening out of so many new collieries, and the consequent cheapening of an article of such vast importance to our national industries and social comfort.

THE BLAST FURNACE AS APPLIED TO THE CUPOLA OF THE IRON FOUNDER.*

By ALEXANDER LAIRD.

From "Iron."

Since the introduction of the cupola or blast furnace by Fulton, of Glasgow, in the year 1802, it has undergone but little change either in form or proportions, and its adoption has now become general in almost all engineering establishments, as being the most convenient and economical furnace for melting pig-iron. The universality of its employment suggests to us either its perfect adaptability to the purpose for which it is required and used, or a degree of laxity, or an indifference to efforts at improvement on the part of engineering generally which is not usually met with.

That it fulfils to a very great extent the requirements of the ironfounder and the engineer is granted on all hands. Still the daily experience of its working as regards the qualities of the metal melted, and its own cost, suggests the need of investigation in a scientific direction, as to the possibility of its modification. Great diversity of opinion exists on this subject, and that not only in relation to the form and proportions of furnace, but also as to increasing and improving the quantity and quality of the iron produced by its agency. The question of reducing the expense of the process is, of course, an important one in addition. Time will not permit me now to enter upon an enumeration of the various devices proposed or introduced for effecting these objects. Many of them have been of little scientific importance or value. In some instances they have been brought forward in the furtherance of particular views held by the proposer, or to uphold a patent in which he had a pecuniary interest. It is only of late that distinct ideas seem to have been formed and advanced on the subject. As a consequence, a great many experiments and tests

* Read at a meeting of the London Association of Foremen Engineers.

have been made, more or less valuable or accurate, and of greater or less importance. If the results of these had been gathered and collated, they might have been of much interest and value to engineering and metallurgical science. The isolated and desultory manner in which they have been made and obtained has rendered them useless to the interests of science, and they afford no general information of any real service.

We have already referred to the universality of the cupola for melting pig-iron. It is now proposed to attempt an elucidation of the principles upon which the cupola furnaces are constructed and worked. Heat is most economically and best applied when used on the principle of being applied under the mass of the material to be consumed or operated upon. By this arrangement the air supplied to support combustion is made to pass through this material on its way upwards towards the furnace-top. In the air furnace, on the contrary, the fuel is never allowed to be in contact with the charges of iron, as the material is situated at the opposite extremity of the hearth. In the cupola the metal and the fuel are deposited in alternate layers upon each other, and thus become intimately blended and united in the course of the fusion and descent of the iron into the hearth. This latter condition will be sufficient to account for that superiority in point of economy which is acknowledged to exist in the cupola as compared with the air furnace.

When cupolas were first introduced into foundries, they were recommended for the great reduction they effected in the consumption and expense of fuel. It has already been explained that it is well adapted by its form and the disposition of fuel and material to work economically. No hesitation need now be felt in asserting also that this economy can be very much increased by raising the depth over the tuyeres; that is to say, by running up the cupola to a greater height, and filling up with more numerous and higher charges. The most intense heat is evolved first at the surface of the flame, or line of union between the gaseous combustible and the air; and as on the cupola the surface extends over the whole lower stratum of the fuel, an immense quantity of heat is thereby generated. This being carried upwards with the intensely heated products of combustion, it becomes deposited in the mass of coke or fuel above. From the slow transmitting power of this substance, it is well able to retain what it receives. By these means it soon accumulates so as to become a magazine of heat of the most intense and dazzling brightness, while the body of the fuel, being decomposed, sinks down to replace that which has been consumed. It is well known that the point of fusion in a cupola or furnace of this kind, using the blast cold, is situated about 2 ft. above the tuyeres. We can thus readily comprehend the importance of great height above the tuyeres. Indeed, the only limit to the increase of this height are those of stability, and the danger arising from irregularity in the working and position of the charges.

There is, it is true, one objection which is sometimes urged by iron-founders against running up the wall of their furnace, and that is the increased labor and cost of raising the materials to the charge-hole of the furnace. This objection is not worth much in an age of mechanical skill, ingenuity, and labor-saving. Why, even without mentioning the resources of applied mechanics, we could, by the utilization of the waste heat and gases, gain sufficient power to overcome this objection to increased height. Much more might be added in favor of high furnaces, and the advantage accruing thereby. As to the necessity of such improvements, it is made manifest by the daily experience of all who observe the vast volume of flame and heat belching from the top of our cupolas, which higher walls and deeper and more numerous charges would assuredly prevent.

We have yet to deal with the higher and more recondite question to be considered, as to the kind or quality of metal in the cupola under the conditions we have just detailed. What, for example, are the influences resulting to the metal from its immediate contact both with the fuel and the blast? By way of illustration, let us say, then, that it is impossible to conceive a more unfortunate and unscientific method for the purpose of producing a highly carburetted or soft cast-iron than the arrangement adopted in the ordinary cupola, or blast furnace. The melted metal, trickling as it does in drops or small rills in its descent to the hearth, must fall into, mix with, and be dashed about by the violent tornado of fresh air from the blow-pipe. Part of it may be protected by the coke, or escape between the tuyeres. Perhaps it may be cooled and oxidized, and, combining with

the flux, melt into a brown glass. Part again will catch fire, burn and blaze with great violence, and, reduced to vapor, be carried up with the stream of air to be again deoxidized by its passage through the carbon in the upper region of the furnace, or it may pass off at the top of the furnace. If to these we add the contingencies of the strong tendency possessed by cast-iron to combine with oxygen at high temperatures, and its extreme inflammability, we shall at once see how readily these latter substances dissolve their union or cast-iron partnership, if we may so call it, to form new unions of their own with the oxygen of the atmosphere. This deoxidization of the iron not only produces a waste of from eight to ten per cent. of material in most cases, but brings the metal, which is well known at times both cold and thick—unless neutralized by the presence of an ample supply of carbonaceous fuel in the form of coke, so that the oxygen of the atmosphere may be thoroughly saturated and mixed before its combination with the material, and the iron rendered hard and stiff. It is a remarkable fact, and one worthy of observation, that softness of castings was a general complaint on the first introduction of the cupola, a complaint which has, however, now died out, and which gives no trouble to the ironfounder of the present day who uses cheap and inferior fuel. The tendency of this combination, as already remarked, was to render the iron soft, and to make it very fluid when melted, so that it might run into the finest and most delicate mould.

Among the many contrivances introduced or adopted to overcome the oxidizing influence of the cupola form of furnace, one of the best and most successful is that of Mr. Eichhorn, which has been experimented with for some time with great success in Germany. The principle of this is, that the blast before entering the cupola is made to descend and pass through a mass of burning fuel. The temperature of the blast is raised, first by contact with the heated bricks, and secondly by radiation into the air chambers from the incandescent fuel; the third, and by far the most important and useful condition, is effected by its actually passing through the fuel.

In the earlier stages of cupola construction, considerable importance was placed on the influence of form and size. The horizontal interior section of all cupolas is circular, however different in other respects they may be, and the principal varieties of cupola may be arranged or classed in four divisions, founded on the form of the vertical section through the trunk.

First, those cupolas which are taken from the hearth upwards to the charging door. Secondly, cylindrical cupolas, or such as are parallel in section under the charging door. Thirdly, expanding cupolas, of which the sides widen from the neighborhood to the tuyere upward; and fourthly, cupolas in which the form is a combination of two or all these figures.

The first and two latter of these forms have become, for all practical purposes, extinct, while the second or cylindrical cupola has been universally adopted. This partiality is easily understood, for in charging parallel cupolas the fireman can more precisely distribute and regulate the proportions of his charges in accordance with the purpose he may have in view than he can in dealing with the tapering cupola.

In the former the materials descend regularly without altering their arrangement, till they reach the neighborhood of the tuyeres, where the iron ought to be melted, and the unconsumed coke is pressed gradually and equally down to make way for the superincumbent charge. Thus the process goes on in a secure and well-ascertained manner, whereas, in the tapering cupola, the firemen are inconvenienced for want of space to deposit their charges, and the materials having to spread into the large expanse below the door, cannot do so equally, and thus, by an unequal mixture of material, the iron is unequally heated. But, to shorten this discussion, it may be said that the best, and indeed the only true means of ascertaining the relative efficiency of various forms of cupolas, is to compare the relative quantities of fuel consumed with those of the iron melted. Economy of fuel and rapidity of fusion, which generally accompany each other, are indeed the touchstone of excellence, and the test of efficiency.

The opinion has already been expressed that the cupola was well adapted, by its form and construction, to work economically, on account of its parallelism of section vertically, and that this economy is capable of indefinite extension by an increase of vertical depth over the tuyere. But the greatest source of waste inseparable from the principles and working of the cupola is the unavoidable loss of heat which takes place by radiation from the outside of the

cupola, and long conduction through the hearth, the amount of such loss being in the ratio of its diameter, and its vertical height. This loss at times is very considerable, and more so in the case of small furnaces, or when the inside lining is thin, and badly constructed. Indeed we have known an instance of this kind where the heat from radiation outside the casing of the furnace was greatly in excess of the thermometer's ability to register it with accuracy. This was on account of the excessively high temperature around the skin. The importance of retaining as much as possible of the fugitive heat to the charges, and preventing its escape from the furnace, whether it be from radiation or from the furnace mouth, ought to be fully recognized in the construction and management of a cupola. Natural and obvious as this condition is, there is nothing more common than to witness everywhere furnaces in use wherein those self-evident conditions appear to have been disregarded or ignored altogether. One effect of this, of course, is to cause an excessive expenditure of fuel and heat which simple mechanical expedients would have obviated and overcome. In reality it is impossible to overestimate the value of a true knowledge of the principles and nature of combustion in furnaces; more particularly this is so in regard to those where the air is forced into the furnace by means of a blast like that of the cupola. The subject, however, is so prolific and complex that we cannot attempt to dispose of it within the limits of a single paper. It will be sufficient to enumerate a few of the more salient points, and then to leave the whole question for reflection and discussion.

Having referred to some of the various forms of furnace and their effects on the operations of smelting, it becomes our duty to refer also to two or three of the most favorable conditions of fuel and blast, viz:

From the nature of the cupola furnace, air should enter in sufficient quantities to maintain the necessary supply of heat, and that, too, at lateral apertures around the alternate layers or strata of materials and fuel, and these, as we have already seen, are arranged under the most favorable conditions when mutually acting and reacting on one another.

Regarding the quantity of fuel per ton of metal melted, there exists a great amount of uncertainty and misconception, and these would be difficult to remove or displace. In endeavoring to do so we should have to deal with the composition and the combustion of fuel. These are so exceedingly various that it would be quite impossible to give anything like a minute description of them.

The task is rendered yet more difficult by the introduction and substitution of cheap and inferior fuel now so common in some establishments, and which is owing to the exceptionally high price of coal. This circumstance overthrows the experience and data of former years, and hampers the efforts and ability of all interested and concerned in furnace economy.

We must now pass on from the question of fuel to that of the blast. Here again we find that there exists much uncertainty and many different opinions. For example, it has long been the belief of some iron-founders that a stiff, sharp blast, or, in plain language, a concentrated jet of air was indispensable in all cases to the economical management of a cupola. Such persons, in realization of their peculiar theory, contract the aperture of the tuyeres and increase the velocity of the blast. On the other hand, there are the disciples and advocates of a more open and diffused blast, and who multiply the tuyeres and work them alternately, in order that they may spread and diffuse the blast over the horizontal area of the cupola. These base their opinions on the results obtained from the air-furnace, where a chimney of a moderate height and proper dimensions is sufficient to generate a heat so bright and strong as to vie in brilliancy with the midday sun. They urge that the distribution of air with the material is calculated to produce a uniform application of heat throughout the whole area of the furnace.

For some time after the adoption of the cupola in cast-iron foundries it was felt to be a desideratum to obtain a uniform and equal blast. Many schemes have been resorted to to effect this important end. The blast cylinder with a vessel inverted in water was devised, among other plans; but it had this drawback, that the air sent into the cupola was damp, and thus hardened the iron. Then the founder had recourse to a bored cast-iron cylinder, but the friction of the piston rendered its operation imperfect and incomplete. Another plan was that of having two cylinders working alternately and exerting an equal force. This was costly in construction, and afterwards

required much power to work it. The summer of 1829 witnessed the introduction of the fan blast—at the instance of Messrs. James and Charles Carmichael—and then the cupola became the most perfect appliance for melting cast-iron which it seems possible to contrive or suggest. Its advantages were, first, with regard to saving of power as compared with the blast cylinder, for it sent double the quantity of air into the cupola. Secondly, that the blast was uninterrupted. Thirdly, owing to the great quantity of air injected with so perfect a regularity of force, the resulting metal was both softer and more uniform in quality than it had hitherto been; and fourthly, that it effected a considerable saving of time in the process of melting.

Having already referred to the effects of a compressed and diffused blast, it will be well to bear in mind that a considerable variation in the pressure, and the quantity of the blast, is necessary to suit the different qualities of the fuel employed in melting furnaces. The variation of pressure is as much as for $1\frac{3}{4}$ lb. to 3 lbs. per in., the stronger blast being used for the more inferior coke. There is, in truth, no doubt that differences in the quality of the coke subjected to the action of the blast do, in some measure, account for separate preferences respectively held in reference to forcible and different blasts. There is, to my thinking, great necessity for regulating the quantity of force of the blast by some fixed rule, if that rule can be found.

IMPROVEMENTS IN THE MANUFACTURE OF GUN-COTTON.

By S. J. MACKIE, C. E.

From "Journal of the Society of Arts."

I must ask the attention of this audience, in the first place, to as brief an epitome of the history of gun-cotton as I can draw, before I go to the main details of my present discourse, which has for its essential object to put before the world some of the chief improvements which have been made in the manufacture of gun-cotton and ammunition therefrom, as about to be carried out in the large and extensive works of the Patent Cotton Gunpowder Company, in the marshes of Ore, near Faversham, in Kent.

I regret that the state of progress in some of the departments not having yet been patented, I am in consequence a little restricted in my explanations; but this circumstance will, I am sure, be accepted as frankly as it is stated, as an apology for any reticence on my part to which, in the interest of the Company, I may be constrained.

The cause of my being before you is very concisely told. The secretary of this Institution having seen some specimens of the Patent Cotton Gunpowder in my office, expressed a strong desire that I should read a paper on the subject in this room; and, although I would have liked to have deferred this discourse until next Session, when I should be able to invite you to see the various processes in practical operation, his request was so pleasantly and perseveringly urged, that, notwithstanding my time is more than fully occupied, I consented, feeling also that in so doing, I should be rendering service by the publication of the extreme care and precaution with which every part and portion of the manufacture has been studied, notwithstanding that no production of gun-cotton or any product of pyroxilin whatever has yet attained to the same degree of safety, purity, or excellence as this new explosive. I may without egotism say this, because I am not the inventor of the "controlled gun-cotton," although, as engineer to the Patent Cotton Gunpowder Company, who have purchased Mr. Punshon's patent, I have prepared the plans of the works, and have instigated the whole of the new machinery by which the gun-cotton and the gunpowder and other compounds from it will be prepared.

To commence, then, with the practical history of modern explosives:—

Xyloidin, the lowest substitution product of the nitro-cellulose class, was discovered by Braconnet, in 1833. It was produced from wood-shavings, saw-dust, starch, and linen fabric, treated with concentrated nitric acid.

Gun-cotton, tri-nitro-cellulose, or pyroxilin, was made known by Pelouze in 1836, who applied strong nitric acid to paper and fabrics of cotton and linen. Ten years later it was produced in an pure form by Schon-

bein, who employed a mixture of concentrated nitric and sulphuric acids for the treatment of cotton wool, the object of the sulphuric acid being to abstract water of hydration, and generally to absorb moisture.

Messrs. Hall, the gunpowder makers of Faversham, in 1846, entered into the manufacture of this material upon Schonbein's original process, the cotton being treated for about one hour with a mixture of 1 part of nitric acid, 1.45 to 1.5 specific gravity, and 3 parts sulphuric acid, 1.85 specific gravity. The gun-cotton produced was washed in running water until no acid was detected by litmus paper, and subsequently it was dipped in carbonate of potash. The finished cotton was sometimes steeped in a solution of nitrate of potash. The manufacture at Faversham was terminated within a year by a disastrous explosion, reputed to have been caused by throwing together in a heap a large quantity of the acid skeins.

At this period also gun-cotton was manufactured in France, at Bouchet, near Paris, where several disastrous explosions occurred; one in a drying chamber, one in a magazine, where it was believed no one had been for several days, and one in a packing place. These disasters put an end to the manufacture in 1848.

The Austrian Government took up earnestly the consideration of gun-cotton in 1852, and practice was made with a battery of twelve-pounder field guns. In consequence of want of uniformity in the shooting and the damage done to the guns, its use for artillery was abandoned. It was, however, received with great favor by the engineers, and was applied with success to mining and submarine operations. General Von Lenk was the moving spirit. The explosion of the magazine at Simmoning, near Vienna brought the manufacture to an end in 1862.

The system of manufacture, as carried on in Austria, was as follows:—Superior quality of cotton was carded loosely and twisted into skeins, the strands being of larger or smaller size according as the future produce was intended for cannon or small arms. These skeins, about five or six to the pound, were immersed in a boiling solution of carbonate of potash, the liquor being afterwards extracted by means of centrifugal machines. The skeins were then washed in clear running water, separately and quickly, either by hand or by allowing the mass to remain in water for three or four hours. They were then again passed through a centrifugal machine, and subsequently dried, in summer by the rays of the sun, in winter in a drying-house, heated by air-pipes, to from 30 to 38 deg. Cent., in the latter place usually taking some four or five days in the operation. The dried skeins were next immersed in a mixture of three parts by weight of sulphuric acid, specific gravity of 1.82, and one part of nitric acid, specific gravity 1.52.

Only two skeins, of about 3 oz. each, of cotton were immersed at one time, and after being stirred about by iron paddles, the cotton was transferred to covered stone jars, each capable of containing six skeins, or about 1 lb., mixed acid being added, if necessary, to bring up the proportion of 10½ lbs. of acid to 1 lb. of cotton. These jars stood for 48 hours in a cool place, in summer time in cold water. After the cotton had digested for this period, the acid was separated, as far as possible, by a centrifugal machine, the men working the acid being protected from the fumes by a wooden partition. The acids extracted by the centrifugals were not used again, in the manufacture of gun-cotton, until after re-manufacture. The skeins of gun-cotton thus made still, however, remained in a very acid condition, and were put into perforated receptacles and immersed in a stream of fresh water, where they were allowed to lie for at least three, and often as long as ten or twelve weeks. Each skein being finally separately rinsed in the stream to remove impurities, the water in the fibrous masses of gun-cotton was again extracted by the centrifugals. The gun-cotton was next treated with a solution of carbonate of potash, as in the preliminary process, and again washed in pure water, after the alkaline liquid had been extracted. These skeins of gun-cotton having been allowed to partially dry, by exposure to the air, were placed in a large wooden tub, containing a solution of silicate of soda, and in which it remained for an hour, the object being, by the formation of a varnish of the silicate over the fibres, to retard the combustion of the gun-cotton, the superfluous water-glass being expressed partly by hand and more fully by the centrifugal. The skeins were then thoroughly dried in a drying-house, similarly as in the preparatory operations, the period of their remaining there being from eight to ten days.

The protection afforded by the soluble glass was found to be very ephemeral and treacherous, of no real protective effect for the cotton, or permanent retarding influence on the explosion.

The Austrian mode of manufacturing gun-cotton was imported into this country in 1863 by Professor Abel, the Chemist to the War Department, and experiments upon a manufacturing scale were instituted at the Royal Gunpowder Works, at Waltham Abbey. Considerable difficulty was experienced, however, from the variation in compactness of the twist, which exerted so much influence upon the rapidity of the combustion of gun-cotton in ordnance, as to necessitate the hand-picking and separation of the mass into two or more portions. Mixed acids were used in the same proportions as the Austrian, sulphuric being 1.84 specific gravity; nitric, 1.52. The cotton was made up into skeins, those of the stout yarn weighing from 4 to 6 oz., and those of the fine yarn from 3 to 4 oz. each. These were boiled in a solution of carbonate of potash, the excess of liquid held in suspension by the skeins being wrung out in a centrifugal machine. The cotton was then washed by hand in a large tank, and afterwards immersed in a stream for 48 hours, when the skeins were again centrifugalled, and the cleansed cotton dried. The acids were weighed off into stoneware barrels provided with taps, two of these receiving the sulphuric acid and the third nitric acid, these barrels being so arranged on a table that the acid would run from the taps into a deep and capacious stoneware vessel fitted with an iron lid and a tap. About twelve hours before the immersion of the cotton in the acids, the skeins, which had been previously dried in the air, were hung up in a large drying chamber, subjected to a temperature of not less than 49 deg. Centigrade.

For treating the cotton skeins with acid the following method was employed:—Into one large deep stoneware pan were drawn off the quantities of mixed acids required for a certain number of skeins; the second pan was fitted with a perforated ledge of iron surrounded by cold water. Some of the acid being transferred to the second pan, two skeins were immersed in it and stirred about for two or three minutes. The superfluous acid was pressed off upon the iron shelf with an iron paddle, the quantity of acid absorbed by the skeins being replaced in the dipping-pan from the first vessel; two other skeins were treated in the same manner, and so on. The drain-skeins were transferred to stoneware jars; six of the large, or nine of the fine, being the quantity for each, any additional quantity of acid necessary to cover the cotton being added, until the proportion of acid to cotton was as 15 to 1. The skeins were allowed to stand in these pots for digestion 48 hours, as in the Austrian process; the contents of the jars were then centrifugalled, by which the great bulk of the acid was separated from the cotton. In the Austrian works at Hirtenberg copper centrifugals were employed; at Waltham Abbey the centrifugals were of iron. The Austrian finished cotton had been quickly immersed by a special machine, under a cascade, where its saturation by water had been effected with great rapidity; at Waltham Abbey the skeins were plunged singly, as rapidly as possible, into a large body of water, and moved violently about; they were then washed by hand, and afterwards immersed in a stream for a period of not less than two days, the skeins being arranged on rows of poles, so placed that the skeins were in a vertical position, the water circulating among them freely. At the expiration of this time the skeins were removed and the water separated by centrifugalling; they were then boiled for a few minutes in a solution of carbonate of potash, and after being centrifugalled, to separate the alkaline liquor, they were again placed on the poles and left in the stream from 14 to 18 days. On final removal from the stream, each skein was washed by hand and allowed to remain in distilled water for some hours. The amount of gun-cotton which theoretically 100 lbs. of cotton should furnish, is 183.3 lbs.; the increase of weight under the process at Waltham Abbey, was determined at 177 lbs. per 100 lbs. of cotton.

The gun-cotton, when finally purified, was dried at Waltham Abbey in the open air, exposed to daylight and very often to powerful sunlight; when dry it was packed in ammunition boxes lined with tinned copper, and having very tightly-closing double lids. The cotton so packed was found upon subsequent examination to exhibit considerable traces of acidity, the odor of which, after the boxes had been closed for 24 hours, was such as to change litmus paper. Experiments were also made

by steeping cotton in the residual mixed acids left after the first steeping, but the lower substitution products obtained were not satisfactory. In 1864 the English Government appointed a committee, upon the recommendation of the British Association, to inquire into the properties of gun-cotton as a substitute for gunpowder, General Sabine being the president, and Colonel Boxer, R. A., and Mr. Abel, the two chief officers of the Royal Laboratory at Woolwich Arsenal, being amongst the members. This committee experimented in that year with 12-pound brass field guns and gun-cotton cartridges made at the small works then already established at Stowmarket for working the patents of M. Revy. The cartridges which were 10 in. long, were divided into outer and inner portions by an intermediate pasteboard cylinder; the charges, from 1 lb. to 21 oz., were made in different degrees of compactness, the most compact giving 1,374 ft., the medium 1,390, and the least compact 1,416 ft. velocity to the projectile; those giving the two former velocities having hollow centres for the expansion of the gases, and the last being made solid. The cotton thread supplied by M. Revy was strongly pressed in winding, and thereby flattened, thus becoming more compact. The next year further cartridges were supplied from Stowmarket of very high degrees of compactness, the most compact of which, 40 lbs. to the cubic foot, had cores large enough to reduce the greatest density to 18 lbs. These gave a maximum velocity of 1,673 ft. These charges, however, enlarged the bore of the gun at every round—in some cases so much, that only three rounds were fired out of the piece.

In June, 1865, Mr. Abel informed the committee that he had made gun-cotton in a new form prepared from pulp, and as the results were satisfactory, he was desirous of making further trials in a more complete manner than he could do with the means at his own disposal. The committee, therefore, provided such materials and facilities as from time to time Mr. Abel required for the application of gun-cotton to artillery and small arms. A memorandum was drawn up by Mr. Abel, in 1868, which states that:—

"Mr. Abel has applied to the production of cannon cartridges the system of reducing gun-cotton to a fine state of division or pulp, and then moulding or compressing it into solid or homogeneous masses of any desired form or density, whereby the desired compactness may be given to the charge without the necessity of employing any considerable amount of foreign matter in the shape of strong cases or cylinders in the construction of the cartridges, the charges being simply enclosed in thin cases or envelopes of brown paper.

"In the cartridges prepared from compressed gun-cotton pulp, which has been gradually developed in the course of experiments with gun-cotton in this condition, the charge consists of three parts:

"1. A small quantity of loose or quickly-burning cotton placed at the rear, and serving as 'priming' to take up the fire from the friction-tube, and to furnish sufficient flame and pressure for determining the proper ignition of the cartridge.

"2. A solid disc of compressed gun-cotton, of which one surface is exposed, and which comprises about one-third of the entire charge. The exposed surface of this disc constitutes the rear end of the cartridge against which the priming is fixed, and the initial pressure in the gun essential to the action of the remainder of the charge is established by the explosion of this disc.

"3. A number of pellets of compressed gun-cotton which constitute the remaining two-thirds of the charge. These pellets are about 0.5 in. thick, and one-third the diameter of the large disc."

The gun-cotton pellets fired from the Enfield rifle were wanting in uniformity, and, although better and satisfactory results were attained from the Whitworth rifle with mechanically-fitting bullets, still the percussioning of both those rifles failed to give that full inflammation of the charge which was desirable. Attempts were also made about this time, by Mr. Abel, to apply the pellets to the Snider rifle. Mining operations were also tried in 1864 and 1865, both with M. Revy's hollow rope, and Mr. Abel's compressed discs. Mr. Sopwith, the mining engineer, also a member of the Government Committee, was associated with these experiments, and, in his report, remarks on the entire safety in the transmission and stowage of gun-cotton in a moist state. He also notes the occurrence of accidents by the ignition of dry gun-cotton charges by friction and sharp concussion. The Committee, in their report of 1867, observe that the value of gun-cotton for submarine purposes has been fully established by the ex-

periments of the Floating Obstruction—otherwise the Torpedo—Committee, of which Mr. Abel was also a member.

In 1867 M. Nobel made public demonstration in this country of dynamite, a mixture of nitro-glycerine with silicious earth, and detonated his charges by means of a strong fulminate-cap. This gentleman has done for nitro-glycerine the like service which Baron Lenk and Professor Abel have done for gun-cotton by their persistent perseverance. M. Nobel devised various modes of effecting this detonation, or initiative explosion. He also showed that nitro-glycerine and its compounds could be violently exploded in the open air, unconfined, by this initiative detonation. M. Nobel also saturated gunpowder with nitro-glycerine, and obtained increased explosive power thereby.

In 1869, Mr. E. O. Brown, the assistant of Professor Abel in the chemical department in Woolwich Arsenal, applied the same means to the detonation of gun-cotton; and Mr. Abel impregnated gun-cotton with nitro-glycerine, forming a compound of increased power, which he called glyoxilin.

Gunpowder, too, has been detonated with improved effect; but the difference is not so marked as in the case of nitro-glycerine and gun-cotton.

The Stowmarket works of Messrs. Prentice, at which Revy's gun-cotton has been made, were greatly enlarged, and the manufacture of Abel's compressed gun-cotton commenced on a large scale in 1870.

In 1870 also Mr. Punshon brought forward his controlled gun-cotton, and experiments were carried on at Woolwich Arsenal, no profitable results therefrom accruing to the inventor at that time, or, indeed, subsequently from the Government. Without doubt the want of substantial official appreciation was a temporary detriment to that gentleman's interest, as the submission of novelties to Government examination, under past or present circumstances, habitually is to those who adopt such a course either in military or naval matters. Independent of all other reasons, the submission to Government of an invention, not at the time commercially in the market, causes commercial men to await the results of official investigations, which, however honest they may be, are invariably tardy, and consequently expose the applicant to most injurious delay. The proper time to put any new article before the Government is, to my mind, when the owner is requested to tender for a large supply.

In 1871, experiments were carried on by the Government Committee on Explosives, under the presidency of Colonel Younghusband, and of which committee Professor Abel was one of the members, for the purpose of showing the safety of Abel's gun-cotton, then being manufactured in large quantities by Messrs. Prentice, at Stowmarket, under the title of the "Patent Safety Gun-cotton Company." The chief of these experiments was the one upon which the "safety" of Abel's gun-cotton was afterwards based and publicly advertised, that Company being at the time under a contract to deliver 200 tons to the Government stores. This experiment was, to my mind, so unsatisfactory and fallacious that, although for years I had been in constant correspondence with one of the chief organs of the press, I never publicly reported it, but I took occasion, as soon as I knew of it, to express my distinct opinion that the experiment was not reliable for the true object of determining the non-explosibility of the residual heated masses of gun-cotton stores in a state of violent conflagration. These experiments were, however, reported in the "Globe," and extracts from that journal were distributed as circular advertisements by the Patent Safety Gun-cotton Company, and gentlemen therein interested.

In July, 1871, the following paragraph appeared in the "Scientific American:—

"A number of mysterious explosions of various nitrogen compounds have attracted the notice of chemists, and some experiments have been instituted, with a view to an explanation of the phenomena. It has been found that nearly all the mixtures composed of nitrogenous substances, and used as explosives, are decomposed with more or less violence by ozone. A powder, in which picric acid was a constituent, caused great damage in the laboratory where it was made, in consequence of the action of ozone. At first the cause of the accident was inexplicable, but careful search traced it to the ozone in the atmosphere. Nitro-glycerine is at once decomposed by ozone into nitric acid and other compounds. Gun-cotton is also destroyed, sometimes with explosive force, and so on through the list of explosive compounds. An extension of these researches may eventually afford

an explanation of the spontaneous decomposition of certain bodies, and may suggest precautions to be observed to prevent a recurrence of the accidents, and it has been suggested that a new test for ozone might be found in this way."

Explosion of gun-cotton as a test of ozone in the air is one, to my mind at least, not suitable for general adoption. There may be, however, a great deal in the philosophy of the subject Ozone is three volumes of oxygen condensed into two volumes; and as we know that ozone is able to effect oxidations which common oxygen is unable to bring about, it is obviously well to have regard to those conditions of the atmosphere in which ozone is most freely generated. All the serious explosions of gun-cotton attributed to spontaneous decomposition have taken place in the hot weather of July and August, and it is in those months that one would expect that ozone would exist in the most active state in the atmosphere. Unfortunately, no records exist, or are anywhere kept of the daily presence of ozone in the air, whereby definite information can be had to serve as data for any scientific investigation of this question. In one of Faraday's charming lectures at the Royal Institution, he took a glass jar, and first demonstrating, by the usual test of iodide of potassium and starch paper, the total absence of ozone from the air within it, he poured into it a little ether. Still no ozone was there; but immediately that he immersed a glass rod heated in a spirit lamp, the presence of ozone was at once shown by the test. In the same lecture he noticed the decomposition of gun-paper by exposure to oxygen. The slow combustion of the sheets of gun-paper so produced would become spontaneous combustion of a very dangerous character where masses of gun-paper or gun-cotton were left under conditions in which the heat of decomposition could be retained and accumulated.

On the 14th August, 1871, the great catastrophe occurred at Messrs. Prentice's place, at Stowmarket, in which 13½ tons of Abel's patent safety gun-cotton exploded, hurling devastation all around the works, killing 23 and wounding 56 of the persons employed. Two reasons have been assigned for this sad occurrence,—one spontaneous ignition, the other diabolical act. That impure gun-cotton had been produced at the Stowmarket factory is certain, because the stock of gun-cotton received into store by the Government at the Upnor magazines, on the Medway, was, on examination after the calamity, found to be in a decomposing state, and the whole of it was consequently at once opened out on the floors and kept well watered.

From the time of this occurrence up to the present moment, gun-cotton has been out of the market, and none of it made in commercial quantities. The nitro-glycerine compounds have thus, in the absence of that cleanly and powerful explosive, had the markets during the past two years entirely to themselves.

After the demolition of the Stowmarket works the Government took up the manufacture of gun-cotton, voting about £5,000 per annum for the establishment of works at Waltham Abbey of some magnitude, capable of producing about three tons per week. These works, which are situated in the High street of the town, have been in operation more than two years, but have recently been suspended on account of an explosion in one of the hydraulic presses.

The works of Mr. Prentice are at this time stated to be in process of resuscitation, and will, as soon as completed, go on with the manufacture of 180 tons—the balance of contract due at the time of the disaster. I have been informed that opposition has been made by the Great Eastern Railway to the license to store at Stowmarket. Those works, when in full swing, were hard pressed to produce five tons a week. The magnitude of the new works at Faversham will stand out prominently in view of these proportions.

It has become therefore—as this audience and every one hereafter who reads this paper when printed in the Society's Transactions will perceive—a matter not only of duty but of conscience on my part in putting up the largest works for the manufacture of gun-cotton ever contemplated, to leave nothing unthought of, nothing undone that human knowledge or foresight can suggest. It is this feeling which so thoroughly animates my assistants as well as myself, and it is a feeling which is most fitly and most honorably encouraged by the directors of the Company, who have sanctioned any provision for security, which has been requested by myself, by the magistrates in granting the requisite license to manufacture, or the Home Office in regard to the security of the public and the workpeople. Undoubtedly the Stowmarket catas-

trophe has given us great annoyance and obstruction on account of the alarm which has been raised through it in men's minds, as well as by the basis which this fear has afforded for interested opposition against the acquirement of a site by our Company. I should, however, be wanting in justice if I did not speak in the highest terms of the knowledge, care, and caution which have been displayed by those of the county magistrates of Kent, who considered the Company's application for a license, under the Gunpowder Act, for the Company's site at Faversham; and personally I am bound also to acknowledge the prompt attention and courtesy received from the Home Office and from the Inspector of Gunpowder Factories, Major Majendie.

The Company's site at Ore extends over more than forty acres, and occupies the shore of the Swale for a length of some 800 yards. The distance from the town of Faversham is two miles, and the extensive gunpowder works of Messrs. Hall are 1½ miles away.

The land lies low, but the marsh is not of wet, unwholesome character; the tertiary strata rise gradually behind it until they attain an elevation of 40 or 50 feet at Uplees and Ore village. The proximity of the sea along so great an extent of frontage affords every facility for the reception and loading of the materials and goods. The situation is clearly advantageous as well as suitable.

We come now to the arrangement of the works. First, there will be small works, in which the process of commercial manufacture will be perfected and assured before the general works to make 20 tons of guncotton per week will be commenced, and these small works will be, after the erection of the large works, continued in operation as laboratory works for the manufacture of small orders of special brands of the cotton-gunpowder, which can be made to any required degree of strength or mildness, to suit particular kinds of rocks, or for any other special purpose. The system therein followed will be (proportionate in scale) the same as that adopted for the general works—namely, full distinction will be made between the wet works and the dry works, or, in other words, the manufacture of gun-cotton in a wet state and the subsequent processes in which it is being prepared for its final dry state as a finished explosive, the buildings being more isolated, and the quantities in work restricted, as the processes approach more and more to dryness.

The site at Ore is divided into two portions, the factory area and the magazine area, the intake jetty for acids, cotton, and raw materials being at one end of the ground, and the output, or shipping jetty, for the finished gunpowder being at the other, and separated by an interval of 700 yards. The magazines are separated from the sea-wall by a space of 100 yards, and from each other by a similar distance, these isolations being ample for explosions of 15 tons, although none of the magazines will be constructed to hold more than five tons. Indeed, throughout the whole of the works all the danger-distances are arranged upon the known effects of the explosion of 13½ tons of absolute gun-cotton at Stowmarket.

This disposition of the works, therefore, commands confidence from its thorough efficiency; whilst the Company's interests are in nowise thereby sacrificed, but, on the contrary, ample margin is afforded for the extension of the manufacture at a future period, when the cotton gunpowder shall have become a standard article of trade, and when the magistrates and the Home Office can, by the light of actual experience, sanction such modifications as in the infancy of the manufacture it is neither desirable to ask for, nor, for mere prudence' sake, to encourage. At the Stowmarket explosion, the material damage—that is, any greater damage than the breaking of windows—was limited to 400 yards. There is nothing at the Ore site whatever—not even a hut or a shed, within nearly twice that distance of the most proximate of the Company's magazines; and, indeed, such is the security afforded by mere distance of unoccupied space around, that 100 tons might be exploded above ground on the Company's magazine area without doing material damage to any of the dwellings in the district.

Equal care and precaution have been taken in the processes of manufacture. The acids will be mixed in the usual proportions, but instead of being stirred about in a primitive fashion in iron retorts, they will be decanted in the required quantities in separate earthenware vessels, and then, after commingling in an earthenware worm, surrounded with water, to conduct away the heat developed, the mixed acids will be received in closed tanks and pumped up

as wanted, the pump being continuously driven from the shafting and returning excess quantities, thus keeping the acids thoroughly mixed. The acids flow in pipes from the store tanks into the service tank, where they are kept at one definite level by a float-valve, and whence, as the acid is abstracted by the cotton in the process of dipping, the supply is automatically let on to replace the quantity used at each operation; the disagreeableness of the acid fumes is thus greatly avoided. After the dipping, the pots of steeped cotton are dealt with most conveniently. These pots of steeped cotton are then left to digest for a sufficient period to insure the conversion of the cotton. The adoption of stoneware and the general neatness and the cleanliness of the above arrangements are far in advance of the iron dipping-pan and pressing grid and rough-and-ready means with which the preparation of the gun-cotton has been carried on in any previous works. The greatest care, too, will be taken in the selection as well as in the cleansing and drying of the cotton previous to steeping, whereby gun-cotton of the purest character will primarily result.

The great barrier to perfection in gun-cotton has, up to the present time, been the tenacity with which the fibre retains the acid; and the presence of acid in the finished gun-cotton has been universally admitted to be the root of all evils, and the direct cause of that spontaneous heating and igniting to which the terrible catastrophes which have alike terminated all the large operation hitherto attempted in Germany, France, and England, have been attributed. Professor Abel, when he adapted the machinery for paper-making to the preparation of gun-cotton, made a most important advance. It was not, however, enough; although it made gun-cotton practicable for military engineering. The system of pulping by means of the rag-beater cut short, it is true, the fibres of the cotton, but it still left the individual particles of the pulp in a fibrous condition, and this necessarily to this extent that a felting property was as necessary for the subsequent compression of the gun-cotton pulp into Abel's discs as the felting property in paper-pulp is required for the manufacture of paper into sheets. But the fibre, however short, still might retain, by capillary attraction, particles of acid in the tube and in the cellular structure of the fibre; and although, therefore, the subsequent washing of the gun-cotton pulp in the poachers was a much accelerated process over the slow method of washing and immersing gun-cotton skeins in running streams, yet under careless manufacture, or short time in the poachers, a retention of acid in the finished discs was highly probable; and indeed complete freedom from a slight percentage of retained acid is by these means impossible, even with the greatest care in manufacture, and this cannot be eliminated by any amount of sampling and testing. Indeed, as against a small residual percentage, a proportion of one per cent. of alkali has always been added as a neutralizer in all the gun-cotton made or accepted by Government. Now, with the warnings before me of the danger accruing from the presence of acid in the finished gun-cotton, I determined to get rid fundamentally of all harborage for it. I made up my mind to crush out every particle of fibre, and to reduce the gun-cotton to an impalpable powder. To this end I passed it between polished rollers, under very severe pressure, and the result has realized every possible expectation. The gun-cotton waste, dripping with water, is thrown into the crushing-mill: the jaws of the rollers seize it, it passes through flattened into a compact mass; it passes through again, and is crushed into a short breaking cake (water jets playing all the time to keep all safe) again and again, and it becomes more and more powdery at each operation, until, in about six passages, it is reduced to veritable dust. Reduced to this condition, the manufacture of gunpowder from gun-cotton became a commercial practicability—became indeed an accomplished fact, as is evidenced by the sample of finished cotton gunpowder which I have now the pleasure as well as the honor to submit to your inspection. What rejoices me in this result is the thorough conviction of the purity of the gun-cotton so prepared; and, as consequent upon that purity, the certainty of the safety which will ever after belong to the finished product.

Mr. Punshon's "controllable gun-cotton" was, at the time it was bought by the Company, exactly what its name indicates. It was gun-cotton of the finest quality which could be made under the old system, the fibre of the cotton being coated and intermixed with sugar and nitre, in the proportion of 67 parts of gun-cotton, 32 of

nitre, and one of cane sugar. This mixture was pressed and cut up into shreds, the cartridges for rifle-shooting being carefully made with charges weighed out to the grain, to secure uniformity of shooting. The sugar is the controlled element. In proportion as the quantity of it is increased or diminished, so the controllable gun-cotton exhibits more violent or less violent action when fired. Of the efficiency of the control I have myself been frequent witness. On one occasion a new Martini-Henry rifle was fired repeatedly with charges of 50 grains of Mr. Punshon's controlled gun-cotton, with perfect safety, and less recoil than from an ordinary charge of Curtis and Harvey's gunpowder. The same rifle fired with a charge of 34 grains of ordinary gun-cotton was burst at the chamber, the lock blown to pieces, and the stock split right down to the guard over the butt.

As I have said, the control by means of the sugar is perfect, and the entire merit of the discovery belongs to Mr. Punshon—nothing whatever in respect to it is due to myself. My own labors and progress begin where his terminate. The crushing machine has enabled me to carry out that which, from the outset of my connection with the Company, has been the desideratum to be attained, namely, the manufacture of a perfect gunpowder, with which cartridges could be filled by measure with the same rapidity as with ordinary black gunpowder. The reduction of the gun-cotton into dust has not only permitted the most perfect cleansing of the gun-cotton from acid, which has no longer a lair to hide in, but is brought on to the surface and instantly cleared away; but this finely-divided state enables the gun-cotton to be regularly and intimately incorporated with the sugar and the nitre, and thus formed into a paste, from which a granulated powder fit for guns can be made. This never could have been done with gun-cotton made upon the old processes, nor under Mr. Abel's, for such gunpowder could not be made even from pulped gun-cotton, since the fibre of the pulp would give a beard to the grains, which would cause them to cling together, and prevent the mechanical filling of the cartridges cases. Moreover, the residual acid would be very likely to prove defiant of all orders to "keep the powder dry."

The incorporating mill, which will be used in the cotton gunpowder works, is a modification of the ordinary incorporating mill, to suit the special requirements of the case. In all these processes, up to and including the granulation, the materials are all of them in a wet or moist condition, and free from danger of explosion, and, indeed, of ignition. The one point of difficulty, that of obtaining the requisite weight of gun-cotton proportionate to the weight of the other ingredients without drying it, has been overcome by constructing a special balance to weigh the quantities by specific gravity. In this way the dangerous element in the manufacture of the cotton gunpowder—gun-cotton—is never allowed to exist in a dangerous state; it is never, indeed, in even an inflammable condition. And, notwithstanding all the world has recently heard about exploding gun-cotton discs in a damp state, no fear need be entertained for stores of gun-cotton kept immersed in water, or from quantities unconfined and wet. I have long understood how far damp gun-cotton could be exploded, and how the circumstances of degrees of moisture, compactness of material, strength of detonation, or proportion of dry gun-cotton to the damp charge, and extent of confinement, are most essential elements in the possibility of the operation. I have myself frequently tried to explode considerable charges of wet gun-cotton waste and gun-cotton pulp, in large glass bottles, without stoppers, floating in water; and in the efforts to get them off have attempted to detonate them, not merely by strong fulminate caps, but also by caps combined with small charges of other strong explosives, the result having been that the wet gun-cotton has been blown all over the place unscathed, whilst the glass bottles have been shivered to atoms by the violence of the detonating charge. Mr. Abel, at the recent torpedo experiments at Stokes Bay, put eight or ten nine-ounce discs of Waltham Abbey gun-cotton, containing about 20 per cent. of moisture, upon the ground in line one inch apart, and attempted to fire them by a detonating fuse implanted in a a dry nine-ounce disc laid atop of the two central wet discs. But only these three discs exploded; the remainder were riven into flakes and the pieces blown about all around to the extent of 40 or 50 paces away from the centre of explosion. At the same time charges of 500 pounds of similar damp gun-cotton were exploded with great effect

in submarine mines in the bay, under a head of 40 feet of water. The confinement and the heat driven into the charge, to vaporize the water into steam, are the essential requirements, as shown by Mr. Abel. Shells filled with water could be exploded by a very small charge of gun-cotton fired into the confined water by detonation, and I expect to see this mode practically applied at some future time in warfare, as the shells would probably be more completely disrupted in this way than by gunpowder, or by bursting charges, or any other explosive. I have long since burst stoneware bottles and pots in this way into innumerable very equally sized fragments. I believe, indeed, that the idea of detonating wet gun-cotton may have been suggested to the chemists at Woolwich Arsenal through my application, when the Company contemplated having their works at Esher—for they have had long and anxious seekings for a location—to store our gun-cotton in unlimited quantity, in magazines submerged in a large pool or basin formed by the waste overflow of the river which passed by the factory, and in respect to which Major Majendie had my distinct approval for consulting with Colonel Younghusband and the members of the Government Committee on Explosives. The power of exploding damp gun-cotton would, moreover, eliminate from the Waltham Abbey process the danger of drying the discs, which, under the system of drying by hot air or by steam pipes, and on metal tables as at Stowmarket, or in enclosed chambers as at Waltham Abbey, is very considerable where the rules for the workmen cannot be rigidly enforced, as they are in the Government factories. To be able to explode Abel's discs just as they come from the hydraulic presses, would not only save drying at the works and facilitate the safety of transport and storage, but it would also save the inconvenience and danger of drying gun-cotton charges on board ships.

Wet gunpowder, whether made of "villainous saltpetre" or of gun-cotton, would be of no use to sportsmen or soldiers in their respective fields. "Keep your powder dry" is as necessary a proverb for cotton gunpowder as any other; and as, therefore, the cotton gunpowder must be dried, it will be dried in the least objectionable manner. Instead of drying it by heat it will be dried in vacuo. It is well known that water will boil at much less temperature as the atmospheric pressure is diminished. This, then, is the principle. The ordinary summer temperature will suffice of itself, and in no case where artificial heat is applied will it go—or will it be possible for it to go—beyond 36 deg. Cent. At this temperature the moisture in our granulated cotton gunpowder can be drawn off by an exhaust, and the powder made ready for packing in the cases to go into magazine for transportation in execution of orders. As this method will shortly receive very important development, I will not dwell longer on it. Neither will I dwell on the process of granulation, as that also is in a stage of further consideration. Left to itself, however, the paste compounded in the incorporating mill will have a natural tendency, in drying, to segregate into small granules, which can be at once sifted into three sizes of very convenient dimensions for small arms and sporting guns.

I come finally to the magazines. These will be sunk some ten or twelve feet below the surface of the earth; the magazine itself will be made of zinc, and it will be entirely surrounded by a pool of water, the breadth of that water ring or wet ditch being 40 feet. In this way not only is a water bed formed in case of explosion, but an earth mortar also; and the effect would be that the gases of explosion would be sent, if not straight up into the air, at least in such a narrow cone of dispersion that all lateral effects of the explosion would be completely cut off from all surroundings, even from the nearest buildings or the works themselves, whilst the solid earth would form an impenetrable traverse between one magazine and the rest. The zinc would give no fragments to be hurled into the air, but would be fused into metallic vapor by the high temperature of the explosion; if indeed the heat of the flames of combustion, which would, unless the magazine were purposely detonated, undoubtedly arise for some time, did not melt the walls of the magazines before the residual mass of cotton gunpowder became heated to explosiveness, and so let in volumes of water from the surrounding pool, sufficient, at least, to prevent explosion, if not to put out the conflagration.

For mining purposes, for cannon, for rifles, and for general shooting, the cotton powder will present special and valuable qualities. Charges for wet or dry blastings of very great destructive power can be made,

and equally a rolling or gradually expanding force can be obtained at will to order. The cotton powder—which is not, so far as we yet know, of an explosive character until confined—will be at least free from those dangers to which the ramming home of the Stowmarket compressed discs exposes the miner and the quarry-man. Upon the cannon powder I shall hope hereafter to have the honor again of meeting you, what has already been done giving the highest promise of unsurpassed results. For rifles and sporting guns the powder will be very soon in the market, when public opinion will criticise it, I feel sure, in a higher manner than I should myself like to do; and therefore, I will content myself with showing you this card of fired cartridges, and this board of results, by which you will see that whilst charges of 75 grains of Curtis and Harvey's No. 6 gunpowder—the best in the world—penetrates at 100 yards range five stout elm boards placed in a rack at ½ in. apart, the bullets from the same rifle were driven into the sixth plank with charges of thirty grains of the cotton gunpowder, the bulk of both being the same, the cartridges being filled from the identical measure. The recoil from the cotton powder was less than the recoil from gunpowder, the smoke very light indeed, without smell, and the barrel of the gun keeps perfectly clean, and its surface is not at all corroded by the action of the gases generated.

And now, gentlemen, thanking you for your patience and favor, I beg you to excuse any self-glorification I may seemed to have indulged in, by believing that that motive has not in the remotest degree actuated either my speech or my endeavors. The patent cotton gunpowder will go into the market untarnished. It will be my most earnest endeavor to keep it without a stain as long as I live. In the conviction of being able to do so I rejoice, and with the endeavor I am sure I shall have your hearty sympathy.

ON THE MINERAL RESOURCES OF INDIA.

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To give, within the limits of such a paper as the present, anything like a complete account of the useful minerals now employed by man, or which only await more favorable circumstances to render their extraction profitable, in a country so extensive as India, is of course out of the question. All that I can attempt is to give you such a general summary of the present state of our knowledge with respect to the distribution and abundance of valuable minerals in India as will enable you to form some idea of the resources available for commercial purposes.

I shall probably state what is new to many when I record my conviction that the mineral resources of India are chiefly remarkable for their paucity, that despite our imperfect acquaintance with the country, we know more of it than of many parts of Europe, and that we are fully justified in believing that although isolated discoveries of much value may be made, and minerals now useless may be mined with profit at some future time, it is improbable that India can ever become a rich country through the development of its mineral wealth.

However, I would not be misunderstood. The idea, not yet extinct, that India is a country abounding with diamond and gold mines, and only awaiting the advent of the enterprising Anglo-Saxon digger and his cradle to pour forth its treasures, is one in which I certainly have no faith. The greater portion of the country is, I believe, either destitute of mineral resources, or those resources occur in a manner which throws serious obstacles in the way of their utilization. The only really important minerals, so far as we know at present, are coal and iron ores, and to these I shall revert presently, first mentioning, as briefly as I can, the useful minerals which are found in India, and in the territories, out of India Proper, which belong to the Indian Government. These minerals are the ores of copper, silver, lead, and tin; native gold, diamonds, and other precious stones, corundum, salt, and petroleum. Some other minerals, such as various kinds of brick clay, slate, or schistose-beds used as slate, and the several rocks used for building purposes, must be taken into consideration amongst the mineral substances used in the

arts, and consequently of value; but it would be impossible to treat of these, even slightly, without exceeding the usual limits of a paper like the present.

Copper has been found in many parts of India, and mined in several places. At present there are mines in various parts of the Himalayas, especially in Kamaon, Gurhwal, Nepal, and Sikkim. These are all worked by natives on a very small scale, and the produce is so inconsiderable that even in Kamaon, where the number of mines is large, and many of them are said to be extensive, English copper is imported to supply part of the local demand. An attempt was made in 1839, at Pokri, in Gurhwal, to work one of the principal mines by European methods, but it was unsuccessful.

In the plains of India, the localities at which copper has been known to occur are very thinly scattered over the country. Neither this nor any other metal can be expected in the vast alluvial plains which form so large a portion of Northern India, nor in the immense tract of volcanic rocks occupying the greater portion of the Bombay Presidency and its vicinity; but even in the areas of metamorphic rock which cover so large a portion of the surface in the eastern and southern parts of the Indian Peninsula, metallic ores in general are remarkably scarce. Still copper has been worked at various times by natives in many places, the principal of which are in Rajputana, the countries south-west of Bengal, and Nellore, Karnul, and Kudapah, in Madras. At present I know of no mines which are regularly carried on, except those near Jaipur, in Rajputana, of which an excellent description was given by Col. Brooke in the "Journal of the Asiatic Society of Bengal," for 1864, p. 519, and the out-turn from these is far from large, but, doubtless, a little ore is from time to time extracted elsewhere.

Much copper ore appears to exist near Chaibassa, in Singhbhum, a country lying west of Midnapur, in Bengal. An extraordinary series of deposits, partly in irregular lodes and partly disseminated through schists, extends across the country for at least 80 miles. Throughout all this tract old workings abound, but there is much fine ore, chiefly carbonate and red oxide of copper, with occasionally copper glance, left in places. At least two attempts have been made by Europeans to work mines in these deposits, but, despite some success, the enterprise was not profitable. The workings were not carried to much depth, I believe never deeper than the old native mines had penetrated, but the impression left upon the managers of the mines was that the deposits decreased in richness below.

Lead is even less frequently met with in India than copper, and, where it occurs, is usually associated, with that metal. Galena, the most common ore of lead, is found in Kulu, Gurhwal, and Sirmur in the North-West Himalayas, and in the former country there are said to be rich veins of the mineral, but they have hitherto been but little mined. I am not aware of any locality in the plains of India at which lead ores are now extracted, but some are found in Ajmir, Raipur, Manbhum, Karnul, Kudapah, etc.

Rich tin deposits are believed to exist in the Tenasserim provinces and Martaban, tinstone being found in the streams which run from the range of mountains dividing the British provinces from Siam. Farther south, on the flanks of the same range, are the well-known stream deposits of Malacca. Though these Tenasserim tin ores have long been known, the excessive wildness of the country which is covered with forest of the densest description, the extreme paucity of the population, and the total absence of roads or any means of carriage, have hitherto prevented all attempts at working.

In India itself tin has been reported from two or three places, but nothing accurate is known of its occurrence.

Silver is said to occur associated with lead in Kulu and Manbhum. In some galena from the latter country as much as 119 oz. of silver to the ton of lead was found, but only a small quantity of ore was assayed. Similarly in some copper ores from Deogurh in the Sonthal perganahs, Mr. Peddington found about 50 oz. of silver to the ton of ore, but other specimens from the same locality produced little or no silver. The locality in Deogurh I have myself visited, but could trace no vein or other regular deposit of ore; the minerals containing copper appeared to be irregularly disseminated in very small quantities through the rock.

Gold is found in many parts of India, but always in very small quantities, in stream gravels. It has been, and is still occasionally, extracted in several parts of the North-West Himalayas, also in Chota

Nagpur, Manbhum, Singhbhum, and the tributary mehals of Orissa, in the Godavari valley, and in some places in Southern India. It is also found in Assam and in parts of Burmah. In all these instances it is obtained from the gravel and sand by rude processes of washing, and the returns are so small that only the poorest of the natives are occupied in the search, which is, as a rule, practised only at the time of year (the spring) when agricultural labor is suspended.

Before closing the list of metals I may mention that an ore of cobalt is found in small quantities near Jaipur in Rajputana, and is employed, it is said, chiefly for coloring enamels. It is probably the mineral known in European works as Syepoorite, Syepoor being evidently a mistaken spelling of Jyepoor or Jaipur. Antimony is found in Kulu and Lahaul, and zinc was formerly smelted, and may perhaps be so still, at Jawad in Mewar. Chromic iron occurs near Salem.

From the preceding details I think it is evident that the metallic ores of India are neither rich nor abundant. In most places where they are found there are remains of old workings, frequently of large extent, and I think that this circumstance tells strongly against the probability of richer deposits being discovered, because it shows that both mining and smelting have long been practised in India. My own belief is that the art of smelting has probably been longer known in India than in Europe, but to this I will refer again when speaking of iron. In speculating on the probable discovery of new mineral deposits, we must bear in mind that India is very unlike such countries as Australia or America, which, until recently, were inhabited by mere savages. For ages the population of India have been acquainted with many of the arts of civilized life, and the great command of labor which the rulers of the country possessed enabled them to carry on the processes which supplied them with such a desideratum as metals, in a manner which would be impossible to wild tribes, the greater part of whose existence is spent in a struggle to procure food and defend themselves from their enemies. It is to the same cause—the command of labor, given without pay as part of the service due from the people to their rulers—that I am inclined to attribute the quantities of precious stones, and especially of diamonds, formerly found in India. It is certain that of late years comparatively few have been obtained, and I suspect the reason to be that the deposits containing diamonds, like the ores of copper and the auriferous sands and gravels of the rivers, do not in many instances really pay the expenses of working them, and never did so; but all were worked, and to a great extent by the princes of the country, to supply the only wealth which they could accumulate, and to furnish the only form of magnificence, except large hosts of retainers, which they could appreciate.

Diamonds were formerly found chiefly in the country around Karnul, Kuddapah, and Ellore, in the Madras presidency, near Sambhalpur, on the Mahanadi, at Weiragad, south-west of Nagpur, and at Panna, in Bandelkhand. At the last-named place, at Banaganpilly, in Karnul, and a few other localities, mines still exist, and a few attempts have of late years been made to reopen those near Sambhalpur, but without success. Both at Banaganpilly and Panna the mines are in rock, the diamonds being found in a conglomerate—which, however, is clearly not their original matrix; but some of the diggings at Banaganpilly are in gravel, the materials of which are derived from the diamond-bearing strata, and at the other places enumerated all the workings appear to have been in loose deposits.

Although rubies, sapphires, and other precious stones are found in Ceylon, Independent Burma, and in the countries north-west of the Himalayas, I know of no locality in British India where they are now obtained; and the only stones procured for jewellery to any extent are the agates, carnelians, and other forms of quartz derived from the trap-rocks of Central and Western India, or from deposits resulting from the denudation of the traps. The largest number of agate pebbles are found in the neighborhood of a small village called Ratanpur, not far from Broach, and in the Nerbudda valley; and the pebbles are worked by the lapidaries of Cambay and Jabalpur. The carnelians from the former locality were known in the time of the Romans.

Although the purest forms of sapphires are not found in India, the coarse varieties, or corundum, are met with in several places in Mysore and Salem, and in Rewah, where a bed occurs several yards in thickness, associated with jade.

I may pass over most of the miscellaneous substances which are mined in India, such as the sulphur and borax of the North-West Himalayas, the greater part of the latter, indeed, coming from beyond the British boundary; the mica of Behar, the shales from which alum is made in Rajputana, Sind, and the Himalayas, the graphite of Kamaon, Sikkim, and Travancore etc. Petroleum has not hitherto been obtained in any quantity in British territory, although a considerable supply is procured in Upper Burmah, and some is known to exist in Pegu and also in Assam. A small quantity also oozes from the ground at several places in the Punjab, and a few years since gas-works were erected at Rawul Pindi, and, I believe, pipes laid down with the intention of utilizing the mineral oil for the purpose of lighting this station. Whether this has been carried into effect or not I do not know; by the last accounts I have heard, it appeared probable that the supply of petroleum procurable was insufficient for the purpose. It is impossible not to express surprise that this point was not ascertained before any expenditure upon gas-works was allowed.

The salt of the Punjab salt range is one of the most valuable minerals of India. The supply has been pronounced by excellent authorities to be practically inexhaustible; indeed, Dr. Oldham declares that nowhere else in the world are deposits of such vast extent and purity known to occur. The Government revenue from the salt exceeds £300,000 per annum.

Having thus briefly noticed the known metallic ores and other minerals of our Indian possessions, exclusive of the ores of iron and of coal, I shall proceed, before speaking of the iron ores, to describe the distribution of the various coal-fields, and the value, so far as it is known, of the fuel to be obtained from them, since the future prospects of the iron manufacture in India depend greatly upon the presence or absence of mineral fuel in the neighborhood of the ore deposits. A report by Dr. Oldham, in 1867, on the coal resources and production of India, being a return called for by H. M. Secretary of State, gives a complete account of the Indian coal-fields known at that time, and of the progress which had been made in working them. Since 1867 much additional information has been obtained concerning the coal-fields in the central provinces, especially those in the basin of the Godavari and its affluents, and considerable progress in the task of mapping and examining the coal-bearing rocks in Western Bengal.

The known coal-fields of India are mostly comprised in a somewhat broad tract of country stretching from the neighborhood of Calcutta, and from a line which may be roughly drawn parallel with the coast of the Bay of Bengal, but at a distance of between 100 and 150 miles from the shore, to about the 78th parallel of east longitude, or a little east of Nagpur. This tract is bordered by the plain of the Ganges valley on the north, and extends locally a little beyond the Godavari to the south. Outside of this limit the only coal-fields of any promise are some in Upper Assam; but deposits of small coal are found in the Khasi Hills, in the salt range in the Punjab, and in Tennaserim. Discoveries of coal have been announced in several other places, but all have, when inquired into, proved to be of no practical value.

It may confidently be stated that throughout the peninsula of India, south of the river Khrishna (and, in fact, south of the Godavari, with the exception of a tract not extending more than 300 miles from the coast of the Bay of Bengal), throughout the whole of Western India, comprising the Bombay Presidency in its entirety, Rajputana, Gwalior, Indore, Guzerat, Kachh, and Sind; in the North-West Provinces, the whole Gangetic plain, and the Himalayas, not only is no workable coal known, but it is highly improbable—and, throughout the greater portion of the area, impossible—that any will ever be discovered. In the Punjab a few deposits, not of true coal, but of lignite, have been met with, but the quantity is very small and the quality inferior. It is thus evident that only a very small part of India can be considered as coal-producing; and even within the boundary I have pointed out, the coal-fields are in general but thinly scattered. Part of this country is still very imperfectly known, but a large portion has been carefully examined.

All the coals contained in the Indian fields, with two or three very trifling exceptions, come from one geological formation, known to Indian geologists as the *Damuda*, the name being taken from the river on which the Raniganj and several other coal-basins occur. The geological age of this formation has long been a matter of

dispute, but is now clearly ascertained to be the same as that of the Australian coal, and to differ very little, if at all, from the carboniferous group of beds in Europe. The fossil plants associated with the coals of India, however, differ greatly from those of the European coal measures, and the Indian coal itself is very dissimilar, both in quality and appearance, its most characteristic distinction being its excessive lamination, due to its consisting of alternate layers of very bright and very dull minerals—the former a pure coal, containing a large proportion of volatile matter and but little ash, the latter earthy, and frequently shale rather than coal.

The coal basins may be roughly divided into four groups:—1st. Those of Bengal, including the coals of the Rajmahal hills, and valley of the Damuda. 2d. Those of Rewah, Sirguja, Bilaspur, Chutia Nagpur, and the tributary mehals of Orissa. 3d. Those of the Nerbudda valley and the hills to the south of it. 4th. Those of Chanda and the Godavari valley. I will enumerate the different coal-bearing areas in each group.

1. *Rajmahal Hills.*—Along the western face of these hills, which run north and south from the neighborhood of Rajmahal on the Ganges, there are several small fields, from which some coal was extracted during the construction of the East India Railway, in order to supply fuel for brick and lime burning. The extent of the fields it is difficult to define, because the coal-bearing rocks are covered at their edges in many cases by higher beds. In each small basin, one of which occurs in every large valley traversing the hills, are several seams of coal, varying in thickness from 3 to 12 ft., but the quality is not in most cases equal to that of the better coal seams in the Raniganj field.

2. *Raniganj.*—This is at present by far the most important of the Indian coal fields, nearly the whole of the coal mined in India being obtained from it. In 1868, the last year of which I have any trustworthy details, the coal extracted throughout the whole of India was about 497,000 tons, of which but 4,000 tons were obtained from all the other coal fields, the remainder being from the Raniganj field. There has been no very great increase in the produce of other coal fields since 1868, with perhaps the exception of the Kurhurbari field.

The Raniganj field commences at a distance of about 120 miles to the north-west of Calcutta, and is about fourteen miles in extreme breadth from east to west, and eighteen from north to south. To the east the coal-bearing rocks are covered by alluvial deposits, and it is uncertain what are the limits of the field in that direction. The known area is between 500 and 600 square miles, a portion of which, about one-fifth, is covered so thickly with formations of later age that it must be left out of consideration in calculating the area available for the production of coal. The seams of coal are numerous, and many of them are of fair quality, sufficiently good at all events for railway purposes, for the East India Railway, and the other railways, which start from Calcutta have, ever since they were opened, been worked with coal supplied from Raniganj. The different seams which are mined vary in thickness from 4½ to 35 ft., and many of them vary in this respect within short distances. The seams near Raniganj itself, where the workings are more extensive than elsewhere, show but little variation, and are of more uniform quality than those in the north and west of the field, where, however, much good coal exists.

Although this coal-field is better known than any other, I do not think that mining operations are sufficiently advanced to enable any trustworthy estimate of the probable yield of coal to be formed. Unquestionably there is an enormous quantity available. Dr. Oldham estimates it roughly at 14,000,000,000 tons, but in truth, many seams, perhaps all, vary in thickness, and we have not data for any accurate determinations. In 1860, there were altogether about 50 collieries at work, many of them, however, being nothing more than small open quarries; the number of the latter has since diminished, but the output of coal had doubled in ten years.

The Raniganj coal-field is traversed by the chord line of the East India Railway, and there is also a branch line to some of the collieries. To this, and to its being the nearest field to Calcutta, is due the much greater development of industry in mining this field than in any other part of India.

3. *Jherria.*—This field commences only 10 miles to the west of the Raniganj coal-bearing tract. It is 21 miles from east to west, 9 miles from north to south, and contains numerous seams of coal, some of them of great thickness. No collieries exist. The

coal, so far as it has been examined, appears somewhat inferior in quality to the better seams near Raniganj, but this is a question which can never be fairly decided without mining.

4. *Bokaro.*—A long strip of coal-bearing rocks, commencing within a mile of the western end of the Jherria field, and extending 40 miles from east to west, with a breadth from north to south never exceeding 7½ miles. The coal is, so far as is known, inferior both in quantity and quality to that of Raniganj, but it is not worked.

5. *Ramgarh.*—A small field 30 square miles in extent, south of the last, and of the same character.

6. *Hoharo or Karanpura Coal Fields.*—Two basins of coal-bearing rocks, respectively 472 and 72 square miles in extent, lying immediately west of the last-named fields, and due south of the civil station of Hazaribagh. They contain, apparently, a considerable quantity of coal of fair quality.

All the above-named coal-fields are in the valley of the Damuda, along which they form a slightly interrupted belt of coal-bearing rocks, extending for 150 miles, and occupying at least 1,500 square miles of country. As the extent of the Raniganj field to the eastward is unknown, this estimate is probably below the truth, and my colleague, Mr. Hughes, estimates the area of coal-bearing rocks in the Damuda valley at 2,000 square miles. Over at least one half of this area, workable coal seams, of considerable thickness, occur within a distance not exceeding 1,000 ft. from the surface. There is, however, a gradual diminution in the thickness of the coal-bearing formations to the westward, and the number of coal seams appears also to diminish.

7. *Kurhurbari.*—A small field, only comprising 18 square miles, of which 8½ contain productive seams of coal. This little tract is in the valley of the Barakar, a tributary of the Damuda, and it lies to the north of the fields previously mentioned. It is 25 miles distant from the chord line of the East India Railway, and a branch has been made to connect the two. The quality of the coal is unusually good for India, equal or superior to the best found in the Raniganj field. Mr. Hughes, after a very careful survey of this field, which, from its small size, affords better means of calculation than the more extensive basins of the Damuda valley, considered that there was sufficient coal, after a liberal allowance for waste, to supply an out-turn of 250,000 tons per annum for 800 years. I place very small reliance upon all such estimates, but still they may give a rough approximation to the truth, and they are as likely to be too small as too large.

The collieries now worked in the Kurhurbari coal-field belong to the East India Railway Company, and I believe it has been found profitable to carry coals for the use of the railway throughout its whole length, and that they can compete successfully in the Punjab lines with the wood fuel which is almost the only local supply in the extreme north-west of India.

I omit from the list some small fields near Deogurh, in the Santhal Parganahs, east of the Kurburbari field, and of the Itkuri field to the west, as no coal of any value has been obtained from either, and the fields are of very small extent.

The second group of coal-fields consists of a number of basins scattered thinly over an immense tract of the wildest country in India. None of them are thoroughly explored, and it is highly probable that when the whole country is geologically surveyed, the number of coal-bearing localities will be largely increased. Great additions to our knowledge have been made during the topographical survey of these regions, coal being now marked on the maps in several places where it was before unknown. I shall merely mention the principal localities.

8. *Palamaan* (Palamow), or Daltonganj, in Chota Nagpur, a field about 30 square miles in extent. Not much coal, but a colliery once existed.

9. *South Rewah Fields.*—Coal exists over a tract of country about 40 miles in length by 20 in breadth.

10. *Fields of Upper Son Valley.*—These are very extensive, but do not appear to be rich, the only seams known being thin and of poor quality.

11. *Fields of Sirguja, Bilaspur, in Eastern Chatisgarh, and country west of Chota Nagpur.*—I class these together, as all we know of them is that seams of coal, many of them of great thickness, occur in several places. At Korba, on the Hasdo river, a seam is exposed altogether 89 ft. in thickness, of which 50 ft. is coal, the rest shale. The coal, however, on assay, yielded a large quantity of ash. These fields will become important in the event of a direct line of

railway being made from Calcutta to Nagpur.

12. *Talchir.*—This field is on the Brahmini river, about 50 miles north-west of Katak. No coal of any value has been found in it.

The third group of coal-fields comprises those in the Nerbudda valley, and the hills of the Satpura range to the south of the river. One locality is of great importance from its proximity to the line of the Great Indian Peninsula Railway. Besides the fields noticed hereafter, small quantities of coal occur at Lameta Ghat, Sher river, Lokurtalai, and other places, and from the first-named a considerable quantity of inferior fuel has been at times extracted for local purposes, but no valuable deposits are known to exist. It is not impossible, however, that some may occur concealed by overlying formations.

13. *Mopani.*—This is the spot at which the collieries of the Nerbudda Coal and Iron Company are situated. The seam, so far as it is known, appears to average about 25 ft. in thickness, but owing to the high dips, numerous faults and dykes, and to the small extent to which boring has hitherto been attempted, the prospects of this field are most obscure. I learn that Mr. Medicott, deputy-superintendent of the geological survey, has been specially detached to examine the neighborhood by boring in the course of the present season.

14. *Tawa Valley.*—Several seams of coal occur near Rawandyo, between Betul and Hoshungabad, about 35 miles south of the Great Indian Peninsula Railway. My own opinion of these seams was rather unfavorable.

15. *Umret, near Chindwara.*—Several seams of fair coal exist, and extend apparently over a considerable tract of country.

The last group consist of coal-fields on the edge of the great sandstone track which occupies the valley of the Godavari and its tributaries, the Pranhita and Wardha, from the neighborhood of Nagpur to near Ellore. Workable coal is known to exist in two localities.

16. *Wardha River, or Berar, and Chanda Field.*—Considering the very recent period at which attention was drawn to this important series of coal deposits, more has been ascertained concerning the beds than in any other coal-fields in India. This is due to the circumstance that all preliminary explorations have been carried out by the officers of the Government, and before any expensive works were commenced. The existence of a very thick seam of carboniferous shale and coal, altogether 50 to 70 ft. in thickness, and containing a fair proportion of useful fuel, has been proved over a large area in the Central Provinces and Berar, and it recurs a few miles further south in the Nizam's territories. The quality of the coal hitherto mined, though inferior to the best seams of Raniganj and Kurhurbali, is sufficiently good for railway purposes, and it is rarely the case in a coal-field that the best coal is the first discovered.

17. *Kamarum.*—This is in the extreme eastern portion of the Hydrabad territory, and about 100 miles north-west of Ellore. Two seams of coal, 9 and 6 ft. in thickness respectively, have been found, and they are of good quality; but they have only been traced over a small tract of country, not exceeding a quarter of a square mile.

18. *Singareny.*—30 miles south-east of the last, and 30 miles north by east of Kamamet. The thickness of the coal is unknown, and further research is necessary, but the locality is interesting as being the most southern yet known in India.

It is probable that other coal seams remain to be discovered in the Godavari valley. Several have been observed near Dumagudem, the head-quarters of the navigation works at the first barrier on the Godavari, but none as yet found is sufficiently good in quality to be of much value.

There is one point in connection with the distribution of coal throughout the different basins which is worthy of notice, and that is the much smaller thickness of the coal-bearing rocks to the westward, and the circumstance that the coal found in them is mostly concentrated in one bed of great thickness, consisting of alternations of coal and shale. In the Raniganj field, where the coal-bearing formations attain their maximum thickness, they consist of two groups, the upper 5,000 ft. thick, the lower 2,000, each containing several seams of coal. The upper group entirely thins out, or is replaced by rocks containing no coal, to the westward, whilst the lower group diminishes greatly in thickness. It is but 600 ft. thick at Mopani, in the Nerbudda valley, and even less near Chanda, whilst the coal is chiefly contained in each case in one large seam, 25 to 30 ft. thick at the first named locality, 60 to 70 (coal and shale) at the last.

Before leaving the subject of coal there are two localities in the extreme north-east of India which require mention; these are—

Khasi Hills.—Some coal of excellent quality occurs in these hills, but the quantity is limited, and the locality about 4,000 ft. above the plains.

Assam.—One of the most promising coal-fields hitherto found in the Indian possessions occurs in Upper Assam, in the Dibrughar and Sibsagur districts. Scarcely anything is known of it as yet except the existence of several seams of excellent coal, containing only from 2 to 5 per cent. of ash. Unfortunately the localities, almost at the extreme east end of the Assam valley, and in a country thinly inhabited and covered with forest, are unfavorable for commercial enterprise.

The coal hitherto met with in Burmah is mere lignite, with the possible exception of a bed recently discovered at Maulmain, concerning which, however, I have no trustworthy information. As the excitement created by the discovery appears to have been succeeded by complete silence on the subject, I fear the seam is of the same small value as other Burmese coals.

From the above details it will be evident that in the portion of India to which coal-bearing rocks are restricted there is a practically inexhaustible supply of the mineral. All the coal-fields, however, are far from the coast, and the majority are in wild, unsettled districts, far from the great centres of commerce and lines of railway. When we proceed, moreover, to compare Indian coal with that of other countries, we shall find a startling difference in quality. Some of the Assam coals are said to cake in burning, but, with this exception, all Indian coals are free-burning, and they will not form true coke, although an inferior coke-like substance may be procured from some of them, and might be employed in manufactures, with advantage. All ordinary Indian coals contain from 10 to 30 per cent. of ash, or even more, and the proportion of fixed carbon rarely exceeds 60 per cent. In many of the best known coal seams of the Raniganj field, which contain 10 to 15 per cent. of ash, the fixed carbon is but little over 50 per cent. The average composition obtained from assays of Indian coals from 74 different localities, as given in Dr. Oldham's report, is:—

Fixed carbon	52·2
Volatile by heat	31·9
Ash	15·5

Whilst the average of five specimens of English coal sold in the Calcutta market, assayed at the same time for the purpose of comparison, gave

Fixed carbon	68·1
Volatile	29·2
Ash	2·7

The result of various trials on Indian railways has been that it requires from half as much again to twice as much of Indian coal as it does of average English coal to do the same amount of work, or, in other words, that Indian coals are capable of doing only one-half to two-thirds the duty of English.

The use of Indian coal has hitherto been restricted to railways, river steamboats, and stationary engines. For sea-going vessels it is very rarely used, owing to the larger bulk taken up by it, and the larger staff of firemen and coal trimmers required in consequence of the increased quantity of coal burnt and of the resulting ash. Even should the price of English coal continue to advance, its place in sea-going vessels will probably be taken by Australian coal, of which a constantly increasing quantity has of late years been imported into India.

For the development of the coal-producing industry of India, we must, therefore, look to local demand, and, above all, to railways and manufactures. If the manufacture of iron in India by means of Indian coal could be successfully established, a greater impetus would be given to coal mining than by any other means I see no reason why, with careful selection, Indian coals should not be employed in manufacturing iron. Care will have to be taken in the selection, some coal containing too much sulphur whilst in certain kinds an unusual proportion of phosphorus enters into the composition of the ash, and doubtless other difficulties will be met with at first, but, although the first attempts may be failures, I confidently look forward to ultimate success.

As its gold, copper, and precious stones formed the mineral wealth of India in the past, and its coal and salt are its richest productions at the present day, I cannot but think that its iron ores will prove its most valuable mines in the future. Unlike the ores of the rarer metals and the coal, the iron-producing minerals of India are

widely scattered; and except in the alluvial plains and the trap area, there are few parts of the country in which none are found, whilst some of the deposits are unsurpassed in either quality or abundance.

The iron ores of India may mostly be comprised under three groups:

1. Magnetic and specular iron ores, and red hematite in beds or veins, amongst metamorphic and subcrystalline rocks.

2. Clay iron ores from the coal-bearing strata, and beds of brown hematite in other stratified rocks.

3. Surface deposits originally derived from metamorphic and sedimentary strata, or from the rock known as laterite. These deposits usually contain either magnetic iron sand or nodules of brown hematite. Laterite itself often contains from 20 to 30 per cent. of iron, and some may be sufficiently rich for smelting.

The first group comprises the most valuable ores of India. It may be again subdivided into two sub-groups, the beds of magnetic or specular ore in the crystalline rocks, and the veins and irregular deposits, mostly of hematite, found in several of the older formations. To the former belong the great deposits of Chanda and Salem, and some of those in Kamaon; to the latter, the ores of Bandelkhand, the Nerbudda valley, and south-east Berar. The supply in many cases is practically inexhaustible. Perhaps the most remarkable deposits are those near Salem, in the Madras Presidency, consisting of immense beds from 50 to 100 ft. thick, or even more, the outcrop of which may often be traced for miles. One of these commences about 9 miles east of Salem, and forms the ridge of a hill 1,500 ft. high, and 4 miles long. Again, on Kunjamullay hill, 6 miles south-west of Salem, there are five bands of magnetic iron from 20 to 50 ft. thick, and they can be traced all round the hill, which is 4 miles in length. These are only two instances out of a large number. At Lohara, in the Chanda district, Central Provinces, there is a hill nearly 2 miles long and half a mile broad, the surface of which is covered with masses of almost pure iron ore, a mixture of specular iron and magnetic, yielding to assay 70 per cent. of metallic iron. So far as I could make out, the whole mass of the hill appeared to consist of this ore. Some thinner bands of magnetic iron ores occur in the gneissic rocks at the southern edge of the Raniganj coal-field.

The chief ores of Bandelkhand and the Nerbudda valley consist of hematite contained in veins and brecciated masses, or in local deposits, often of great extent and richness, derived from the denudation of the breccias. Although these deposits do not approach in abundance the wonderful masses last referred to, they are able to afford a large quantity of excellent ore.

The clay iron ores of the Raniganj and other fields of the Damuda valley are similar to those of the English coal-fields, and the quantity is large. A large series of specimens from the Raniganj coal-field yielded on assay an average of nearly 39 per cent. of iron. In the other coal-fields these beds are either sparingly distributed or wanting. In some places there are large deposits of hematite near the base of the coal measures.

The principal iron ore of Kamaon is obtained from an argillaceous band, containing large quantities of red hematite, with smaller proportions of brown hematite in the tertiary sub-Himalayan rocks. The ore bed is from 10 to 20 ft. thick; it has been traced for a long distance, but it appears to be only locally rich.

The various surface deposits supply a great portion of the ores used by the native smelters, but much labor is necessary in collection, and the quantity procurable is often insufficient for large works. Still, these deposits would in places yield a very considerable supply, and might be usefully employed mixed with the richer ores.

I cannot better terminate this paper than by a very brief account of the native iron manufacture in India, and a short notice of the efforts hitherto made by the Government and private individuals to introduce smelting on a larger scale.

The iron manufacture in India dates from a period far beyond the range of history. In many parts of the country stone circles, cromlechs, kistvaens, and similar relics occur, precisely similar to those found in Europe; but whereas, in the European localities, the only implements found beneath these ancient remains are of stone or bronze, in India, in numerous instances, weapons and other objects of iron have been met with. It is not, of course, certain that the stone circles of the two countries are contemporaneous, but still there appears every probability that those of India are of greater antiquity than the earliest use of iron in Europe.

The present method of making iron varies somewhat in different localities, but generally the process is carried on in a small clay furnace, three to five feet high, and about a foot in diameter inside. The blast is supplied in Bengal, Orissa, the Northern Circars, Bastar, the lower Godavari Valley, etc., by foot bellows of peculiar construction, elsewhere by the ordinary Indian goat-skin bellows, worked by the hand. The fuel employed is charcoal, and no flux is used. The smelting usually lasts 8 to 10 hours, after which a mass of impure malleable iron, weighing from 10 to 20 lbs., is found in the bottom of the furnace. This is purified by reheating in an open hearth and hammering. The resulting iron is usually of excellent quality.

There are various modifications of this process. On the Godavari I found a wandering gipsy-like tribe of blacksmiths, who simply mix ore and charcoal in a hole in the ground, and by the means of foot-bellows extract a small mass of iron, which they proceed at once to hammer into any implement which may be required. In Bhirbhum, on the other hand, there are furnaces which produce upwards of a hundredweight per diem. The improvement in this case was first made by an Englishman, but has been adopted by the natives. But, however modified, the process is extremely rough and wasteful, the amount of labor and the proportion of fuel necessary being excessive, whilst the quantity of iron produced is very small. The natives engaged in the work are of the lowest caste, and are always miserably poor. The manufacture of iron throughout India is rapidly decreasing, in consequence of the forests being cleared.

The idea of introducing European methods of smelting dates from the commencement of the century, when, owing to the war, the introduction of charcoal iron into England had become difficult, and it is curious to note that the original intentions of the first association which ever attempted to manufacture iron on a large scale in India were to supply the wants of England. The original promoter, Mr. Heath, a Madras civilian, applied to the Government of Madras for aid in his endeavor to start iron works, and thus commences a very curious history, told, with great prolixity, in two Parliamentary blue books. The first transaction was, perhaps, the most remarkable of the whole. The Government of Madras did not like to advance money for the establishment of iron works, but they gave Mr. Heath a contract to supply the Government with cotton, with the intention that he should apply the profits derived from the cotton contract to his iron manufacture. Unfortunately for the latter, the price of cotton rose, and instead of profiting, Mr. Heath lost by his contract. However, he still kept to his project, and about 1825 succeeded in obtaining an advance of money from Government and in forming a company to establish iron works at Porto Novo, near Cuddalore, south of Madras, Polamputee, near Salem, Trincomalee, and at Beypoor, in Malabar. The former commenced to work about the year 1833.

It would be tedious to go through the long history of the Madras iron works. From beginning to end it is one unbroken tale of ill-success, despite much aid from the Government, and all the shareholders, including Mr. Heath, lost largely. One company failed, and another was started to take its place. Several serious errors appear to have been committed, one of the principal of these being the distance of the works at Porto Novo from the supplies of ore and charcoal; another the faulty construction of the works in the first instance. The gradually-increasing cost of charcoal, in consequence of the destruction of forests near the works, and the distance from which it was necessary to bring fuel, also added to the expense; but after every allowance has been made, the utter collapse of the undertaking, and its unprofitable results from beginning to end, are difficult to understand. The works were, I believe, finally given up about 1860.

One attempt at least was made to establish iron works at Raniganj, and one at Jubalpur, but they came to nothing, and in the former case at all events, no furnace was ever built.

Just before and after the mutinies, the commencement of railways in India, and the consequent demand for iron, seem to have greatly stimulated attempts at manufacture. One or two trifling attempts had already been made in Bengal, but in 1837 Mr. Sowerby, an engineer, was engaged by the Government to report on the iron ores of Kamaon, and subsequently, to construct iron-works. At the same time some blast-furnaces were built in the same country by private individuals; all proved failures. Another attempt was made by a Calcutta

merchant, at Mahamadbazar, near Suri, in Bhirbhum, at a distance of about 100 miles from Calcutta, and close to the line of the East India Railway. I was ordered to report upon these works in 1860, and their prospect appeared to me fair, the only doubtful question being the supply of charcoal. However, they were abandoned shortly afterwards. Lastly, some works were erected by the Government, at Burwai, on the Nerbudda, under the direction of Mr. Mitander, a very able Swedish metallurgist. I believe this was by far the most promising attempt ever made to construct iron-works in India. Mr. Mitander was admirably suited for the work; he had had much experience in making iron with charcoal, and was at the same time a good metallurgist, with sufficient scientific knowledge to enable him to overcome difficulties. After many assays all preliminary difficulties had been overcome, the works were ready for the production of iron, and nothing was required except the aid of some European workmen to superintend the natives; but meantime, unfortunately, Colonel (then Captain) Keatinge, the present Chief Commissioner of the Central Province, to whom the establishment of the works was due, had been transferred to other duties at a distance, and, there being no one to urge the importance of completing the experiment, the Government, in a fit of economy, after spending 7½ lakhs (£75,000), dismissed Mr. Mitander and closed the works, which they offered for sale, naturally without success. This was in 1864.

The Nerbudda iron-works had, to the best of my belief, a fairer chance of success than any others which have ever been attempted in India. Ore and limestone abounded in the neighborhood, and a large forest, extending for many miles to the east and north east, furnished a sufficient supply of charcoal. Above all, a competent manager was in charge. It is greatly to be regretted that the experiment was never fully carried out, and that, after the large expenditure made, it was never ascertained by trial whether iron could be made with profit or not. Equally unfortunate is it that no record has been published of Mr. Mitander's various experiments of the plans adopted by him for burning and storing charcoal, etc. Should new works be started all will have to be done over again. The works have now been made over to Holkar, with the territory on which they stand.

All the iron-works I have mentioned employed charcoal for fuel; the use of Indian coal for iron-smelting has yet to be attempted. Several men of experience have been sent out at various times by the Government of India to report on the prospects of iron manufacture, and last autumn Mr. Bauerman was despatched for the same purpose. It is to be hoped that his report will lead to some definite result. The increasing price of iron in England is most favorable to the chance of the manufacture proving profitable in India.

I will sum up in as few words as possible my views as to the mineral resources of India. The known ores of copper, lead, and silver, and the deposits containing gold and diamonds, are of small value. Valuable tin ores exist in the Tenasserim provinces, and still more valuable beds of salt in the Punjab. Coal abounds, but is limited to a comparatively small portion of the country, and the quality is inferior; iron ores occur plentifully, but hitherto they have been very little worked. I think I am justified in my opinion that India, taken as a whole, cannot be considered rich in minerals.

REPORTS OF ENGINEERS' SOCIETIES.

SOUTH MIDLAND INSTITUTE OF MINING ENGINEERS.—Mr. S. Watkins read a paper upon "Colliery Winding Engines." The subject had been suggested to him by the Secretary of the Institute, and it was treated in a manner which demonstrated that the author was in every way qualified to handle it exhaustively. Interestingly Mr. Watkins reviewed the history of the colliery winding-engine, sketching the character of the machinery which our forefathers found suitable to their day. Upon getting well into the subject he said that the most important requisites of the colliery mining engine were that it should be self-contained; the centre of gravity should be as low as possible; the building should be light and cheap, as it might be more or less of a temporary character; to obtain stability of structure, the pull and thrust of the engine should be in the line of the main structure thereof; the engine should be as light and portable as possible consistently with strength; friction and wear, occasioned by cumbrous and complex working parts, should be avoided: the engine should be as compact and accessible as possible, so that all might be under the eye of the tenter; and, lastly, the valve gearing should be simple and easy to handle, and so arranged as to give a variable expansion. No engine, so far as he was able to judge, completely met the first seven requirements, excepting the direct-acting horizontal engine, and no valve gearing would, he thought, so completely meet the eight requirements as the link motion with reversing eccentrics. The author then discussed at length the many ad-

vantages of the direct acting horizontal engine, and gave examples which were supposed to be condensing engines having perfect vacuum in the condenser. Coupled engines altogether met the difficulty of "getting on centres." The steam parts of winding-engines, when sliding valves were used, should be as long and narrow as practicable, inasmuch as a short stroke for the starting handle was desirable. Among the numerous diagrams which illustrated the paper Mr. Watkins exhibited a drawing of a horizontal condenser engine, made by Messrs. Nolett & Co., engineers, of Ghent. This engine set forth most of the advantages he had mentioned to be gained from the use of horizontal engines. Of piston speed a good deal, he said, had been remarked, but except that it enabled small engines to be raised in the place of larger engines, he was not aware that there was an advantage in high speeds. Concluding, the author said that for compactness and convenience in working he thought that the two-cylinder engine working direct on to the drums would compare favorably with the cylinder engine driving the drums on the second motion. There was a brief discussion, and the author was warmly thanked for his communication, which was deemed of so much importance by the members of the Institute that it was determined it should be set down for further discussion at the next meeting.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—At a regular meeting the Society held July 2d, 1873, Mr. Leverich presented the following:

As set forth in the Constitution, two of the objects of the American Society of Civil Engineers are: the professional improvement of its members, and the advancement of engineering in all its branches.

Among the means whereby these objects are to be secured, are: the collection and dissemination of current professional knowledge, and the foundation of a library and museum.

The professional improvement of members comprehends the collection and distribution among them, of all experimental knowledge relating to their profession, both of the past, finished and recorded, and of the present, incomplete and unwritten. This includes the discussion of theory, the results of practice, the accounts of success and failure, the teachings of experiment, and the examination of data; and thus will largely promote the advancement of engineering in all its branches.

At best the purpose of the Society will be but partially effected by the collection and dissemination of current professional knowledge, unless the same is also securely preserved; this involves the foundation of a library and museum.

The library of the American Society of Civil Engineers should contain all that has been published relating to the history and prosecution of engineering, maps and profiles of every canal and railroad, their complete reports, those of the several municipal, state and federal departments, and select published matter referring to other and miscellaneous works, public and private It should also contain standard works of reference in science and art, and indeed lack nothing required of a library by the student or accomplished engineer seeking professional knowledge. The museum should be an adjunct of the library, and illustrate in matter much that is there described in words; efficiently representing by models and samples, the proportions, form and physical characteristics of the agents of engineering effort.

Much professional knowledge is recorded in the several technical journals of the day, and this is almost inaccessible to the busy members of a profession which allows but little time or opportunity for exhaustive reading. Complete treatises are published from time to time, upon theoretical or practical subjects, full of matter valuable to engineers who are unable to possess or peru-e them. These, as issued, should form a part of the library of this Society, and be made available to members.

The advantages of such a library should be placed at the command of all connected therewith, wherever they may happen to reside, so that on request, complete examinations upon specified topics could be made, pertinent extracts copied, and proper references given; therefore—

Whereas, the foundation of a library and museum, which contains within itself all accessible published matter relating to the history, theory and practice of engineering, the construction and management of public improvements, and the methods and cost of manufacturing operations, with illustrations by models and samples of the results thereby obtained, must be invaluable, not only to the profession, but to all who are interested in the pursuit or the application of practical knowledge.

Resolved, That a Committee, consisting of the President and nine other members to be named by him, with power to fill vacancies, be appointed to devise a plan whereby such a library and museum may be founded; the funds obtained for its collection, management, increase and maintenance; a suitable place secured, where it and other possessions of the Society may be preserved, and its advantages enjoyed by members and others connected therewith, irrespective of their location; the Committee to report to this Society at the meeting before October 1st, next; the report to be printed and distributed to members for examination and approval, and action thereon made a special order for the annual meeting, to be held November 5th, 1873.

The resolutions were adopted.

IRON AND STEEL NOTES.

THE NAIL AND CHAIN TRADE OF THE BLACK COUNTRY.—Relative to this subject some information of interest is given in the Reports of the Factory Inspectors, which have just appeared. When a nail-master commences business it appears he opens a warehouse somewhere in the district which goes by the name of the Black Country; but to carry on a large trade in hammered nails he must have supplementary warehouses in several districts. At each of these warehouses, on certain days of the week, nail-rod iron is delivered to the nailmaker, sufficient for him and his family to work up in a week, and at the expiration of that time he is expected to return the iron made into nails, when he receives a further supply. The whole family are usually engaged in the work; the district, in fact, swarming with nail and chain shops for the manufacture of all kinds of handmade nails, and from the strongest cable chains to the smallest chains in use. Men or women are masters or mistresses of the shops, the men

making the heavier and the women the lighter chains, while the children act as bellows-blowers for either the one or the other. With all these people the price of rod iron or slack coal is of the first importance; an undue or unexpected rise in the price of these articles seriously affecting the trade. At the best of times it appears that the average weekly earnings of a nailmaker are not more than from 12s. to 16s. per week; and the women on an average, earn from 6s. to 8s. a week; the children from 3s. to 5s. It is worthy of note, too, that, while the highly-paid foremen and workers in iron mills are refusing to work more than nine hours for a day's pay, the nailmakers persist in declaring that the Workshop Act will ruin them, as, at present prices, they cannot get a living by working twelve and fourteen hours a day. It is estimated that in the headquarters of this trade 5,000 people are regularly employed. The work is carried on in small shops with from two to ten hearths each, and these are to be met with behind almost every cottage. Each hand hires his or her own "standing," and is in nowise responsible to any one, provided the rent is paid. The wholesale trade is in the hands of many small factors, who have warehouses near their colony of workers for the storing of bar iron, and for the sorting, weighing, and storage of manufactured goods. Some of these masters employ numerous receivers who work exclusively for them. The hands, it is stated, have many difficulties which oblige them to work irregularly, as they are compelled to wait for orders and bundled iron; and even when these are obtained they are at the mercy of the carriers of the district. As a rule, four days' work is considered a full week; and from the above causes the hands are obliged to work overtime, frequently beginning at six in the morning and going on until ten in the evening. This is naturally very severe labor for the children who blow the bellows, and who are obliged to work the same hours as the elder *employes*. In consequence of this it is mentioned that the great majority of the children are stunted and delicate, their faces appearing to be considerably more ancient than their years warrant. One of the great evils to the regular workers in the business is that nearly the whole of the inhabitants of the district are brought up to the trade, even if they do not follow it as a livelihood; and, if a stagnation occurs in their regular occupation, they resort to nailmaking, thus injuring those who work at the business constantly. The hours of labor are not fixed; the hands leave and commence work when they think proper, often breaking off in the middle of the day and recommencing when ordinary people are going to bed.—*Iron*.

THE IRON TRADE IN FRANCE.—The condition of the markets exhibits no improvement, and trade is almost as dull as possible; the fall in prices caused no demand. Present rates are simply maintained because no one knows what to do; the only point on which all seem to agree is that the next real quotations must exhibit a serious fall; it would not, however, be wise to calculate too surely upon this.

In spite, however, of the present state and estimated prospects of the trade, we hear of new establishments almost daily, but those which were commenced in better times are being completed very leisurely. The grand desideratum is, of course, a fall in the price of coal, but as is well said by an industrial writer in Paris, so long as France depends in a great measure upon foreign supplies, she must follow their steps, and cannot take the initiative. On the other hand coal is more than usually abundant in Paris just now, but that is simply caused by the absence of demand elsewhere. Many of the new constructions are the result of improvements and extensions of old works, to be paid for out of the profits of the two past years. This is wise policy, and "if," says the "Moniteur des Interests Materiels," "all who had made great gains had employed a portion of their profits in introducing into their works those important, almost radical, improvements which have transformed the iron trade during the past three years, they would have been better prepared to support the present reaction."

The new blast furnace established by MM. Desforges et Cie. at Marnaval, Saint Dizier, is now in full work; their works are on the plan of the new English establishments.

The Denain Company has commenced the construction of its steel works, the estimate for which is said to be between three and four millions of francs; the works will not, however, be completed till about the middle of next year. The company is said to have two millions of orders in hand, the Northern Railway being largely interested in the concern in order to insure its supply of rails.

In connection with this subject it may be well to mention that the Assembly has nominated a Commission of fifteen deputies to inquire into the state of the coal trade in France, and if possible, to find means to bring the production to a level with the consumption, and at the same time to calm the excitement caused by the present state of things; a committee appointed to consider the proposal were decidedly unanimous in its favor, on the ground that the same motives had induced England to institute a like inquiry.

The price of coal in Paris is maintained; the Assistance Publique invited tenders the other day, when the demands varied from 26 f. to 38 f. per ton; the offers were not accepted. As to iron, the last quotations are: Merchant iron, first class, 325 f. to 330 f., with a difference of 20 f. per class; flooring iron, 335 f. to 340 f.; plate for construction, 440 f. to 450 f.; pipes, 280 f.; columns, 240 f.; gutter pipes, 335 f.; balcony castings, 450 f. to 480 f. per ton. Old iron finds no market at present prices. Orders are scarce in the construction shops.—*Iron*.

AMERICAN *v.* ENGLISH HARDWARE, TOOLS, ETC.,—Advices lately to hand from New York respecting the wonderful development of the iron and hardware industries of the United States are exciting serious apprehensions in Birmingham and its neighborhood. The accuracy of these advices is to some extent confirmed by the serious diminution of orders for certain classes of hardware, the manufacturers of which have hitherto found in the American market their principal customers. Nor does it appear that our rivals in the States are content with satisfying the requirements of their own market, for their productions are already supplanting English goods in Canada, and to some extent in Australia and New Zealand. A correspondent of the "Birmingham

Post," writing from New York on the 5th June, says: "It is a common boast that in a very short time the superiority of Yankee skill and ingenuity will force a market in England itself for many articles of American hardware; that Yankee cutlery will appear on English dinner tables, and Yankee saws, augers, and chisels be preferred by the carpenters of Birmingham and Sheffield." These statements are to some extent corroborated by the advices now being received by the merchants in Birmingham and Wolverhampton. There can be no doubt, as the "Times" remarks, that the American manufacturers have turned to profitable account the recent course of events in the English labor market. For some years the American manufacturers have had to contend with the disadvantage of dear labor; but this very circumstance has in the long run proved of benefit to them, seeing that it has enforced the application of labor-saving machinery on a much larger scale than has been attempted in this country. The superiority of American fine iron castings has long been acknowledged, and in the earlier years of hardware manufacture in the States, the dearness of labor was largely compensated for by the substitution of cast for wrought-iron in almost all kinds of produce. This advantage was, however, obtained at the expense of the quality of the goods for strength and endurance, and the necessity of increased mechanical appliances for the saving of hand labor became apparent some years since to the leading manufacturers of the States. The wonderful system of labor-saving machinery now existing is the result. Railway fastenings, door-locks, spring-bars, curry-combs, tin wares, and some descriptions of edge-tools are among the classes of produce in which American competition is beginning to be seriously felt in Birmingham and the South Staffordshire district. Last year's produce of iron rails in the States was nearly 1,000,000 tons, of which Pennsylvania alone yielded nearly one-half. Other descriptions of finished iron are also being produced in large and rapidly-increasing quantities, and at the present rate of progress the shipment of iron from England across the Atlantic will soon be a thing of the past.

RAILWAY NOTES.

PENNSYLVANIA RAILWAYS.—STATISTICS FOR 1872.—There are 117 railways operated in this State. The total capital stock paid in is $439,864,345.82; the funded debt $325,413,597.66. The length of the main lines is 4,179 miles There are 1,618 miles of double track, and 1,784 miles of siding. The total cost of roads and equipments was $524,395,133.45. There are 3,720 engines, 1,538 first-class passenger, 250 second-class, and 734 baggage and mail cars. The freight cars number 58,630, and the coal, ore, stone and tank, 64,628. The bridges number 2,623, of which 481 are iron, 1,774 wood, and 368 stone. Depots or stations, 1,890; tunnels, 51; engine houses and shops, 483. Length in miles laid with steel rails, 1,434. Value of real estate exclusive of roadway, $22,257,832.

The gross tonnage for '72, was 75,687,726, of which 17,327,120 was through freight. Passengers carried, 35,170,294. Miles run—by passenger trains, 24,512,000; by freight trains, 58,291,626; by coal trains, 11,070,813. The tonnage carried embraced: Anthracite coal, 29,577,404 tons; bituminous, 12,670,406; petroleum and other oils, 2,768,638; pig iron, 1,634,691; railroad iron, 785,286; castings, etc., 941,611; iron and other ores, 3,899,558; lime, stone, slate, etc., 885,765; agricultural products, 5,258,299; merchandise and manufactures, 5,335,294; live stock, 2,282,486; lumber, 3,213,911, and other articles 4,969,857 tons.

The total expenses of maintaining and operating, repairing machinery, etc., were $86,2 5,900. The receipts were: passengers, $32,745,965.72; freight, $88,977,894.98; mail and express, $5,013,378; use of cars, $1,646,446 49; miscellaneous, $6,134,223.66—total $134,818,848.92.

The number of persons killed was: Passengers, 33; employés, 254; others, 285—total, 572. Injured: Passengers, 160; employés, 615; others, 213—total, 988.

The capital stock paid in, up to 1872, aggregated $439,864,345.82. The funded and floating debt is $342,076,170.75.

Comparative statement of passengers carried for four years on roads into Pittsburg:

	1869.	1870.	1871.	1872.
Allegh ny Val.	433,387	507,157	578,084	779,959
Erie and Pitts.	.....	.....	.....	265,985
Pennsylvania.	4,229,363	4,352,769	4,699,985	5,250,393
P., C. & S. L..	421.016	437.268	540 516	611,201
P. and Conn..	462,124	531.011	706,423	781,994
P, F. W. & C.	2,727,633	1,916,129	1,969,867	2,106.251
P., Va & C .	.....	.....	.....	4,000

Comparative statement of tonnage for three years:

	1870.	1871.	1872.
Allegheny Valley....	855,556	1,008,798	1,320,289
Erie & Pittsburg ...	....	. ....	1,141,437
Pennsylvania	5,427,401	6,575,843	7,844,779
P.. Cin. & St. L·	913.906	1,236,803	1,429,115
Pittsburg & Conn....	580,074	717.299	980,780
P., Ft. W. & C.....	1,740,584	2 047,114	2,408.162
Pittsburg & Ch'n....	....	.....	22,392

A PROPOSED NARROW GAUGE.—We condense from the Buffalo "Commercial:" "The enterprising village of Springville has long been anxious te secure direct railroad communication with Buffalo. When the B. & Wash. railroad was projected efforts were made to induce that line to connect with S., but that village was found to be too far out of the direct course to make the detour desirable. And when the B. & Jamestown railroad project occupied attention, S. made another desperate effort, in vain. Now the people of Maumee and Miami, O., are in nearly the same situation. They have been trying for years to secure railroad communication with Toledo. They now propose a narrow-gauge railroad to be operated with dummy engines—resembling more a strong substantial street railroad than a regular railroad. A frame-work of wood is to be con-

structed and heavy strap-iron rails laid on the stringers. The scheme is so satisfactory to the business men of Toledo that $25,000 were subscribed the first day. It looks as though this kind of railroad might satisfy all the conditions of the B. & Springville scheme. It would not cost much more than a good plank road, and for several years would do all the business offering; locomotives and cars would be comparatively inexpensive, while trains could be run at fair speed. But the best features is that it will prepare the way for a first-classs narrow-gauge railway. The line should be located with as much care as though a regular T iron and heavy tie track was to be laid; then, as it needed repairing, the heavy rails and ties could take the place of the framework and strap-iron rails. After the entire track had been relaid the light rolling stock could be replaced by the improved narrow-gauge locomotives and cars.

THE Direction of the Government Railroads of the Netherlands has published the results of some experiments in regard to the preservation of sheet iron used in railroad bridges. From thirty-two sheets half were cleaned by immersion for twenty-four hours in diluted hydrochloric acid; they were then neutralized with milk of lime, washed with hot water, and while warm dried and rubbed with oil. The other half was only cleaned mechanically by scratching and brushing. Four of each kind were then equally painted with red lead, and with two kinds of a red paint of oxide of iron, and with coal tar. The plates were then exposed to the weather; and examined after three years. The result was: (1) That the red lead had kept perfectly on both kinds of plates, so that it was impossible to say if the chemical cleansing was of any use. (2) That one kind of iron oxide red paint gave better results on the chemically treated plate than on the other; in fact, a result equal to that of the plate painted with red lead, while the other kind of iron oxide red gave not very good results on the plates when only scratched and brushed. (3) That the coal tar was considerably worse than the paint, and had even entirely disappeared from those iron sheets which had not been treated chemically, but only cleaned by brushing.

THE Glasgow street tramways are now fast approaching completion. The extent of streets now laid is ten miles and three-quarters, and from six to seven miles of the lines authorized have yet to be made, a portion of which has just been commenced. An important line of tramways between Greenock and Gourock has been opened within the past few days.

A SUSPENSION railway bridge across the Mississippi at Carondelet, six miles below St. Louis, is now proposed. The project for a bridge at that point is not a new one; but the design originally contemplated a truss bridge on piers, with a 400-ft. channel-span, several minor spans, and a 200-ft. draw for use at high water. This plan being deemed detrimental to navigation, the act was amended so as to require a rigid truss bridge with a space of 500 ft. The Company now propose a bridge with four spans—two 600-ft. channel spans, and two 300-ft. shore spans. Instead of a truss bridge, resting on river piers, the new plan provides for the two 600-ft. channel-spans upon the suspension principle, and the two shore spans upon the truss principle. The topography is highly favorable to this plan. A low rocky bluff juts into the river as a promontory, half a mile north of the Vulcan Iron Works. Not only does the bluff afford foundation for the western abutments and approaches, but the bed of the river is on a shelving rock gradually deepening towards the east. Here also the river is contracted to its narrowest breadth in that locality.

ENGINEERING STRUCTURES.

CONSTRUCTION, ETC., ON THE CONTINENT.—Tenders were invited to be sent in before 1 o'clock on the 19th of July, for the dredging, maintenance, and improvement of the navigable channel of the Marne between the Dizy Lock and the Department of the Seine and Marne, for the three years 1873–74–75. The estimated cost of the work is 24,000 francs per annum. The estimates and all particulars to be obtained at the Prefecture of the Seine, at the Luxembourg, 4th division—2d bureau; certificates to be received and signed by the engineer-in-chief of the works of the Marne, eight days at least in advance of the above date.

The authorities of the town of Bordeaux announce that on the 24th of July they will adjudicate publicly the lightning of the town by gas. Full information to be obtained of the secretary at the Mairie.

The concession of the local line of railway from Périers to Carentan, Manche, is announced for adjudication on the 30th of July. The maximum subvention is fixed at 27 500 francs per kilometre. Apply at the Prefecture of the Manche, at Saint Lo.

The provincial government of Mons, Belgium, will shortly accept tenders for the construction of a line of railway from Blaton to Ath, ballasting and permanent way not included; estimate, 660,000 francs, and deposit fixed at 35,000 francs.

Amongst coming works may be mentioned the new line of railway proposed by the Lyons and Mediterranean Company, from Nimes to Teil. This line is proposed to pass by Saint Gervasy, Besonce, Remoulins, Aramon, Villeneuve, Laudun, Bagnols, and Pont-Saint-Esprit, and its length is 118 kilometres; a branch is to be formed to Uzès, 16 kilometres in length, which will pass over the valley of the Alzon on a viaduct 45 metres high.

Plans for the embankment of the left bank of the Gironde, between Goulée and Verdon, proposed by M. Tessier, are now on public view at the Mairie of Lespare.

A project, presented by the Orleans Railway Company, is now under official inquiry for five local lines in the department of La Sarthe; and another, by MM. Benoist and Séguin, for an apparently competing line.

The cantons of Switzerland are convened to examine a project of M. Saint Léger & Co. for concession of a line of railway from Bulle to Toune, Wimmis, following the right bank of the Sarine, by Grandvillard and Lessoc, crossing the Sarine at Tine, and recrossing it at Moulins. The concession of the proposed line from Toune to

Konolfingen, to be eventually continued to Diesbach and Kiesin, is to be submitted to the federal council in the coming session.

The Belgian Government is intent upon the completion of its public works; the amount set down in the budget for the extension and completion of railways for the coming years is 23 millions of francs.

The minister argued that tramways should be made, as feeders of the railways, and, above all, the formation of narrow ways in localities where railways could only be established at great cost. On the 24th of June the Chamber voted 130,000 francs for the lighting of the Scheldt; 3 millions for improving the connections of roads and railways, for which the minister only asked half a million; 800,000 francs for the improvement of the river Yser; 5 millions, instead of two asked for by the minister, for the enlarging and deepening of the Ghent and Terneuzen Canal; and, two days later, 20 millions were voted for the maintenance and furnishing of common schools.

A more important work, in a commercial point of view, perhaps, than any of those above named, is almost sure to be put up to public competition shortly; the great canal of Saint-Louis, on which more than twenty millions of francs have been expended, is at present almost unused for want of a railway from Saint-Louis to Arles, uniting the canal with the Mediterranean lines, and a system of quays on the Rhone, between the basin of the canal and the river, to allow of transhipment. For years the Imperial Government was memorialized and petitioned without effect on this subject; but the other day a number of the deputies of the Rhone, the Ain, the Loire, and the Gard, obtained the absolute promise of the Minister of Public Works that the works should no longer be put off.

THROUGH THE ROCKY MOUNTAINS.—The tunnel will be about twelve miles long. Its greatest depth will be 6,000 ft. at James' Peak. It will make Middle Park readily accessible from the eastern portion of the Territory; will show what is the mineral and geological character of this section, and will extensively advertise the country as the scene of an enterprise twice as large and a hundred times as important as the Mont Cenis tunnel. Colonel Heaton will use the diamond-pointed drills, and thus not be obliged to keep in operation numerous blacksmith shops. They will be driven by machinery. And it is expected that the tunnel will progress at the rate of 5 ft. per hour, or 60 ft. per day. Early next year, work will commence from Middle Park.

Already considerable work has been done. The mountain has been graded down for the face of the tunnel; a flume, 1,300 ft. long, has been built from the creek, by which a fall of 25 ft. is obtained for the purpose of turning an over-shot wheel, by means of which the tunnel is to be supplied with air; a strong levee has been built to prevent the water of the creek from overflowing and embarrassing operations in the tunnel; a large boarding-house, 60x25 ft., and two stories high, has been built; a substantial bridge has also been built over the creek on the road leading to the Lake Gulch country.

The objects of the tunnel are to afford a means of working the discovered mines rapidly and cheaply, to discover and open new veins, and to afford a track for a railway. It will strike the Bobtail first of known mines, and 400 ft. below the present tunnel.

The effects of the success of this enterprise can hardly be estimated. It may cause to pass through our section, and under our mountains, all, or nearly all, the transcontinental travel.

The company by name the Sierra Madre Tunnel Company, of Colorado, have ample capital, and will push the project rapidly to completion. Though the enterprise is of such magnitude as to daze the imagination, and to stagger and bewilder the judgment, yet, if the mining resources of the country are what we all believe them to be, it is not chimerical, and is sure to be a source of profit to the company, and of incalculable benefit to the Territory.

ORDNANCE AND NAVAL.

THE NEW 8-INCH HOWITZER.—After an extensive series of trials at Shoeburyness, an 8-inch rifled howitzer of 46 cwt. has been definitely introduced into the siege train. Being light and short, and firing a small charge of powder (up to 10 lbs.) behind a 180-lbs. shell, it depends on high elevation and a curved trajectory for extensive range. It thus combines the property of the howitzer and of the mortar, and is mounted upon a special wrought-iron carriage, constructed to give as much as 40 deg. elevation to the piece; 5,000 yards range has been obtained with this high elevation, and with considerable accuracy. Objectionable as curved fire generally is, it has special advantages in siege operations for breaching sunken or unseen parapets; while at close quarters, for defensive purposes, light guns capable of throwing large shell, or heavy case-shot, are often very advantageous. But it is an indication of the over-refinement which characterizes our unpractical and would-be scientific artillerists, that the 180-lbs. shells for this 8-inch howitzer are so contrived as to be useless for the 8-inch gun, though the shell is of precisely the same weight and calibre as that used in that gun. This complication of ammunition is observable also in the two 12-inch guns, the ammunition of which is, for similar reasons, not interchangeable either. The contents of the 180-lbs. shell for the 8-inch gun is 14 lbs. 9 oz. of powder, while that of the howitzer is only 13 lbs. This difference can hardly arise from any necessity of providing a stronger shell, as the charge employed in the gun is 35 lbs., and that in the howitzer only 10 lbs. But the uninterchangeableness of the shell is caused by the difference in the rifling. Hardly two rifled guns out of the twenty-five natures in the British service have their grooves cut at the same angle. Almost every imaginable angle has been tried, without any definite rule having been discovered. Hence the new 8-inch howitzer has a *uniform* angle of twist throughout the bore, the angle of spiral on the shot and in the barrel corresponding; but the 8-inch gun is rifled, with an angle of twist *increasing* from nothing at the origin of the grooves to one turn in forty calibres at the muzzle, its shell being consequently rifled at the fixed angle of one turn in forty, and its barrel at an ever-varying angle. If an increas-

ing spiral be good for the gun, why not for the howitzer? This unnecessary variety of ammunition is a very serious question on active service, for the work of war rarely falls equally on all the guns in a battery, and it is often essential to take the stores of the unused ordnance to supply the fighting guns. Moreover, with two kinds of 180-lbs. shell for 8-inch calibres, with differences of rifling hardly appreciable to the naked eye, there is great danger lest the wrong one be used, and a jam consequently take place, which, if it occurred in loading, would place the piece *hors de combat*, and, if in firing, would spread death and destruction throughout the battery. The complications arising from the needless multiplication of calibres is bad enough, but that each calibre should have several varieties of rifling is monstrous. These objections were so strongly felt in the smooth bore period, that the varieties were, for ships of war, brought down to two kinds; thus the same 32-pounder shot or shell fitted any of the eight natures of 32-pounder gun from 13 cwt. up to 58 cwt., and the same 8-inch shot or shell fitted any of the five natures of 8-inch gun from 25 cwt. up to 95 cwt., and these were the only two calibres of projectiles used in a ship of 131 guns, whatever the weights of the several pieces. But we are getting so theoretical without science, and so clever without learning, and so smart without experience, and so soldierlike without practice, that all old rules are thrown to the winds, and chopping and changing, according to the rule of thumb, is the order of the day. The new 8-inch howitzer follows this rule, both as to its uniform rifling and as to its studded ammunition.

THE FISH TORPEDO.—The new English submarine rocket, commonly known as "The Fish Torpedo," has been privately tried in the canal at the Royal Arsenal, in the presence of several officers of the Royal Laboratory, and the result is said to have been satisfactory; but, as great care was taken that only authorized officials should witness the experiments, nothing definite is known upon this point. The torpedo, when full-rigged with the explosive chamber at its head, and the propelling screw and steering apparatus at its tail, is 20 ft. long; the iron fish-shaped body, which forms the middle portion, being merely the vessel which carries the motive power, an atmospheric engine working by compressed air with a pressure of 1,000 lbs. on the square inch. This is the first of these torpedoes made in England, but it is understood that a similar system has been tried in Austria with great success. Certain improvements have been made in the design at the Laboratory, which are expected to prove highly advantageous. The explosive charge will be 160 lbs. of gun cotton, fired by percussion on striking a ship or any other obstacle; but in the experiments made at Woolwich the charge was dispensed with. About 30 of these marine monsters are in course of manufacture at the arsenal.

RUSSIAN ORDNANCE.—Weight for weight, it would appear that Russian heavy ordnance is more powerful than the English. The Russian 25½-ton gun of 11 in. calibre, throws a 550 lbs. shot or 431 lbs. shell, with 91¼ lbs. of powder; whereas the similar English gun throws a 530 lbs. shot, or 402 lbs. shell, with 85 lbs. of powder. We have also a gun of the same weight, but of 12 in. calibre, which ought therefore to consume much larger charges. As a matter of fact it does not do so, and therefore throws its 600 lbs. shot with 15 ft. less initial velocity than that from the 11 in. calibre. If it could endure the same charges as other guns of 12 in. calibre, it would be far more effective than its 11 in. brother of the same weight.

The Russian 8 in. 8¾ ton gun may be compared with the Woolwich 8 in. 9 ton gun. The former throws 195 lbs. shot or shell with 31¼ lbs. powder; the latter, the heavier piece, throws 180 lbs. shot and shell, with 35 lbs. powder.

The Russian 7½ ton gun is of 8 in. calibre, whereas ours is of 7 in., but the Russians throw 195 lbs. shot or shell, as against our 115 lbs. shot, with 25 lbs. of powder, as against our 30 lbs. charges.

The Russian 3¾ ton gun may be compared with our 3½ and 3½ ton 64 pounders. The former are of 6.03 in. calibre, ours of 6.3 in. The Russian gun throws a 96 lbs. shot or 93 lbs. shell, with 16 lbs. and 19 lbs. charges; whereas the Woolwich gun throws only a 64 lbs. shell with 8 and 6 lbs. R. L. G. powder. Even the 4¾ ton Woolwich gun is less powerful than the Russian 3¾ ton gun, throwing only an 80 lbs. shell, as against the Russian shell of 93 lbs.

Besides these weapons, which, being of the same weight, can be fairly compared, the Russians have a 7½ ton gun of 8½ in. calibre, but without any increase of charge, the shot being 5¾ lbs. heavier than that of the 8 in. gun of similar weight. This calibre seems too great for the metal.

Their 9 in. gun of 14½ tons throws a 300 lbs. shot or shell with 52 lbs. charge, and bears, therefore, weight for weight, a fair proportion to the Woolwich 9 in. gun of 12½ tons weight, which throws a 250 lbs. shot or shell with 50 lbs. powder charge. The Whitworth trial 9 in. gun was of 14½ tons weight, and threw a 310 lbs. shot with 50 lbs. of powder.

As the Russian velocities are higher than ours with similar charges, it would appear that the battering power of their heavy ordnance, weight for weight, is much superior to that of Woolwich rifled guns.

GERMAN ARTILLERY.—The Germans are evidently not inclined to rest on their laurels, but are busy improving every branch of their army, making experiments and trials constantly with new small arms, new guns, and new powders.

It is, of course, very difficult to ascertain what is going on in the midst of secret military commissions, but some few facts are known, and many more assertions are afloat. Thus, it appears certain that a complete separation of the siege artillery and the field artillery will be carried out at once, and this while the mounted artillery, which was found only useful when attached to divisions of cavalry, will be reduced, and the foot artillery largely increased and formed into regiments; these points seem to be absolutely determined on. With respect to guns, nothing seems to be known yet, but it is believed that the proposed introduction of bronze guns will be rejected in favor of Krupp's new cast-steel fours and sixes.

The Shrapnel shell may be said not only to have deen adopted, but to have thoroughly estab-

lished itself during the late war, when it was but partially used by the field artillery. Its effects were found, however, to be so decided at the siege of Strasbourg, and in January, at the siege of Paris, that the whole of the field as well as the siege artillery is to be supplied with them, probably to the exclusion of canister or any other kind of mitraille.

With respect to small arms, while the army is being supplied as rapidly as possible with rifles converted on the Beck principle, experiments are constantly being made with new weapons, amongst which a modification of the Manser rifle seems to be the favorite.

It is said, with what amount of truth does not appear, that the bayonet will be laid aside, but it would be rather hazardous to accept this assertion as a positive fact.

The whole system of the composition of the cavalry is being overhauled, and important changes are talked of, such as the forming of the great majority of the cavalry in divisions, and placing them under the immediate orders of the commander-in-chief.

It is evident that the German Government is not inclined to let past experience pass without fructification.

BOOK NOTICES.

OUR NAVAL SCHOOL AND NAVAL OFFICERS. Translated from the French of M. de Crisenoy. By Commander RICHD. W. MEADE, U. S. N. New York: D. Van Nostrand.

Of course the Navy refered to in the above title is not our own, but the French. The interest and usefulness of this little essay for American readers may be inferred from the following extract from the translator's preface:

"It occurs to me that our Gallic friends have some faults and peculiarities in their system of Naval education and government which our own service shares in a measure with them, and I have reached the conclusion that if 'done into English' and published, the remarks of M. de Crisenoy may impart to the brows of my professional brethren in authority a wrinkle or so, to the ultimate benefit of our Naval Service."

The routine of exercises of the French Naval Cadet, and his subsequent duties as a graduated officer, are sketched with a caustic but doubtless accurate pen, referring in both instances to the period immediately preceding the late Franco-German war.

VAN NOSTRAND'S SCIENCE SERIES—CHIMNEYS FOR FURNACES, FIRE PLACES AND STEAM BOILERS. By R. ARMSTRONG C. E. New York: D. Van Nostrand.

As this valuable little treatise has recently appeared in the pages of this "Magazine," no special reference to its merits is needed now; but the series of which this is the first number deserves an introductory notice. Every engineer recognizes the importance, to himself at least, of the possession of concise treatises on such practical subjects as relate to his own line of professional labor.

The time necessary to sift what is wanted out of extended treatises and reduce it to a form fitted for use, is not always to be commended. The table-books, containing results and formulas only, are regarded with distrust, unless there has been a previous acquaintance with the methods of deduction. A concise rationale of the subject alone satisfies such requirements as occur at times to all who engage in the pursuits of applied science.

Encyclopedia articles sometimes fulfil the required conditions of conciseness and accuracy, but their application to use is as often attended with a painful distrust as to whether the principles evolved belong to the last century or the present one.

Again, engineering literature is receiving constant additions; much of it valuable, most of it in too transient a form to be widely serviceable. Yet the valuable working formulas of the future are to be evolved from the successful operations of to-day.

Now, to present the best modern essays on applied science in a compact form, is the object of this new "Science Series." The second of the series will contain the valuable paper on "Boiler Explosions,' and the third, the essay on "Retaining Walls," as it appears in the present number of the "Magazine," with some supplementary notes gathered from latter essays.

REPORT OF A TOPOGRAPHICAL SURVEY OF THE ADIRONDACK WILDERNESS OF NEW YORK. By VERPLANCK COLVIN. Albany: Argus Co. For sale by Van Nostrand.

We have in this report the first reliable maps of the Adirondack region. Those published heretofore were compiled from the labors of the Geological Survey, and consequently from very scanty data. The triangulation established by Mr. Colvin accurately located the mountains and lakes, while a long series of barometric observations established their heights. The results of the latter are tabulated and thus given quite fully.

A new interest attaches to this region since it was proposed to make it a public park, and this report will in consequence be widely read.

A PRACTICAL MANUAL FOR CHEMICAL ANALYSIS AND ASSAYING FOR IRON. By L. L. DE KONINCK and E. DIETZ, with Notes by ROBT. MALLET, F. R. S. London: Chapman & Hall. For sale by Van Nostrand.

The metallurgy of iron is certainly a subject of sufficient importance to warrant the preparation of a treatise upon the chemical analysis of iron ores, and the products of iron manufacture.

The work before us comprehends the instruction of the novice in analysis, in the complete manipulation of the laboratory processes so far as iron and its more frequent associates are concerned.

The work is divided into parts as follows:

Part First contains a description of the reagents to be employed, and tests of their purity.

Part Second gives instruction relative to the apparatus belonging to the laboratory.

Part Third deals with the method of volumetric assaying.

Part Fourth treats of the assay of iron ores and slags by the *wet* method.

Part Fifth gives the methods of treating the same substances by the *dry* method.

Part Sixth treats of the analysis of malleable iron, cast iron and steel.

Part Seventh is devoted to the examination of fuels.

An outline of the process for examining zinc and lead ores, is added as a proper supplement to the preceding chapters.

The work supposes on the part of the learner, such a knowledge of general chemistry as is obtained in the average collegiate or academic course of study. It is clearly an instruction book prepared by able hands.

ELEMENTARY PRINCIPLES OF CARPENTRY. Composed from the work of T. TREDGOLD, C.E. With Additions, etc. And A TREATISE ON JOINERY. By WINDHAM TARN, M. A. CARPENTRY AND JOINERY: An Atlas of Engravings to accompany the above. 4to. Lockwood & Co., 1873. For sale by Van Nostrand.

The former edition of Mr. Tarn's work formed, as is well known, one of Weale's "Rudimentary Series," and it gave a brief outline of the carpentry of floors and roofs, with a popular account of the action of forces in the various pieces composing a truss. The new work retains much of the old one, but it is greatly enlarged, and is, in the main, an abridgment of Tredgold's folio work on "Carpentry." Of course, the progressive knowledge, through experiment, of the strength of materials, soon renders the most recent information obsolete; and accordingly Mr. Tarn has made such alterations, additions, and corrections, as modern research demanded. He explains the mode of calculating the strains on the parts of a truss by geometrical diagrams; and the tables of scantlings for the timbers of roofs are calculated by the help of this process. Joinery, which was overlooked in the former edition, has 52 pages allotted to it out of 288; and forms an important feature in the present work, the various technical terms and modes of operation adopted by the joiner being explained with great fulness considering the limited space at the author's disposal. The letter-press is illustrated by sixty-seven excellent diagrams, so far a complete treatise in itself; but references are also made to the Atlas published, as formerly, in a separate and independent volume in large quarto. These two volumes together form a complete Treasury of Carpentry and Joinery, and Mr. Tarn deserves the greatest praise for his skilfully-chosen additions and improvements. The small volume, at least, should be in the hands of every carpenter and joiner in the Empire; and the whole should be accessible to all, especially to apprentices. Having little faith in the efforts of twaddling philanthropists in the matter of technical education, we have a certain conviction that books of this sort, issued and edited by able and experienced men and published at a wonderfully low price, will repay masters a thousandfold in taking pains to encourage its purchase by all their more intelligent workmen.

MISCELLANEOUS.

ANGLO-AUSTRALIAN TELEGRAPHY.—A Select Committee of the Legislative Assembly of New South Wales has recommended the Government of that colony to join with the Governments of the other Australian colonies in offering, if need be, a subsidy to the telegraph companies interested in the existing Anglo-Australian line to induce them to lower their rates. The committee, influenced by a large amount of evidence brought before it, reported in favor of some arrangement for getting telegrams of important news by cable to be supplied to the public free. A message of 100 words three times a week was estimated as likely to cost Australia £10,000 per annum. The committee further advised the New South Wales Government to obtain the concurrence of the other Australian colonies to the laying an alternative cable from Normanton to Singapore.

ST. JOHN HARBOR.—It appears that the Government of the Dominion of Canada, in order to have exact data upon which to act in regard to the construction of a breakwater at the entrance to St. John Harbor, has commissioned a staff of engineers to make a thorough survey and report upon the expenditure required to meet the wants of the port.

BRAZILIAN SUBMARINE TELEGRAPHY.—The Telegraph Construction and Maintenance Company (Limited) is making the cable of the Brazilian Transatlantic Telegraph Company. Hooper's Telegraph Works have on hand a cable to connect Para with the southern frontier of Brazil, and Para with St. Thomas. Messrs. Siemens have contracted for a cable to be laid from the province of Rio Grande do Sul to the River Plate. Each of these cables when made will be in the hands of a separate company. The expedition of the Telegraph Construction and Maintenance Company (Limited) to lay the Madeira section of the Brazilian and European cable is expected to sail at the close of this month.

BRITISH NORTH AMERICAN COAST SURVEY.—The English Imperial Government has given instructions to its officers in charge of the British North American Coast Survey, stationed at Newfoundland, to take fresh soundings at Port Hood, Cape Breton, and off Crane Island in the St. Lawrence. It is understood that the waters at these places have shoaled considerably since the last survey.

QUEBEC HARBOR.—A revival of a project matured some 25 years since by Captain Boxer for the improvement of Quebec Harbor is recommended. Captain Boxer proposed to construct one long quay along the river front to deep water, with piers stretching out into the water 20 ft. in length, at intervals of every 600 ft., or thereabouts.

PENNSYLVANIA COAL.—The deliveries of Pennsylvania anthracite coal thus far in the Pennsylvania "coal year" have amounted to 7,807,460 tons, against 7,703,508 tons in the corresponding period of 1871-2. The deliveries of Pennsylvania bituminous coal in 1872-3 were 8,778,663 tons, against 8,580,203 tons in the corresponding period of 1871-2.

SOUTH AMERICAN TELEGRAPHIC PROGRESS.—Telegraphy is making great strides in South America. It is expected that in September, Valparaiso, Santiago de Chili, Buenos Ayres, Monte Video, Rio de Janeiro, Bahia, and Pernambuco, will be linked together by the magic wires.